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Module 2

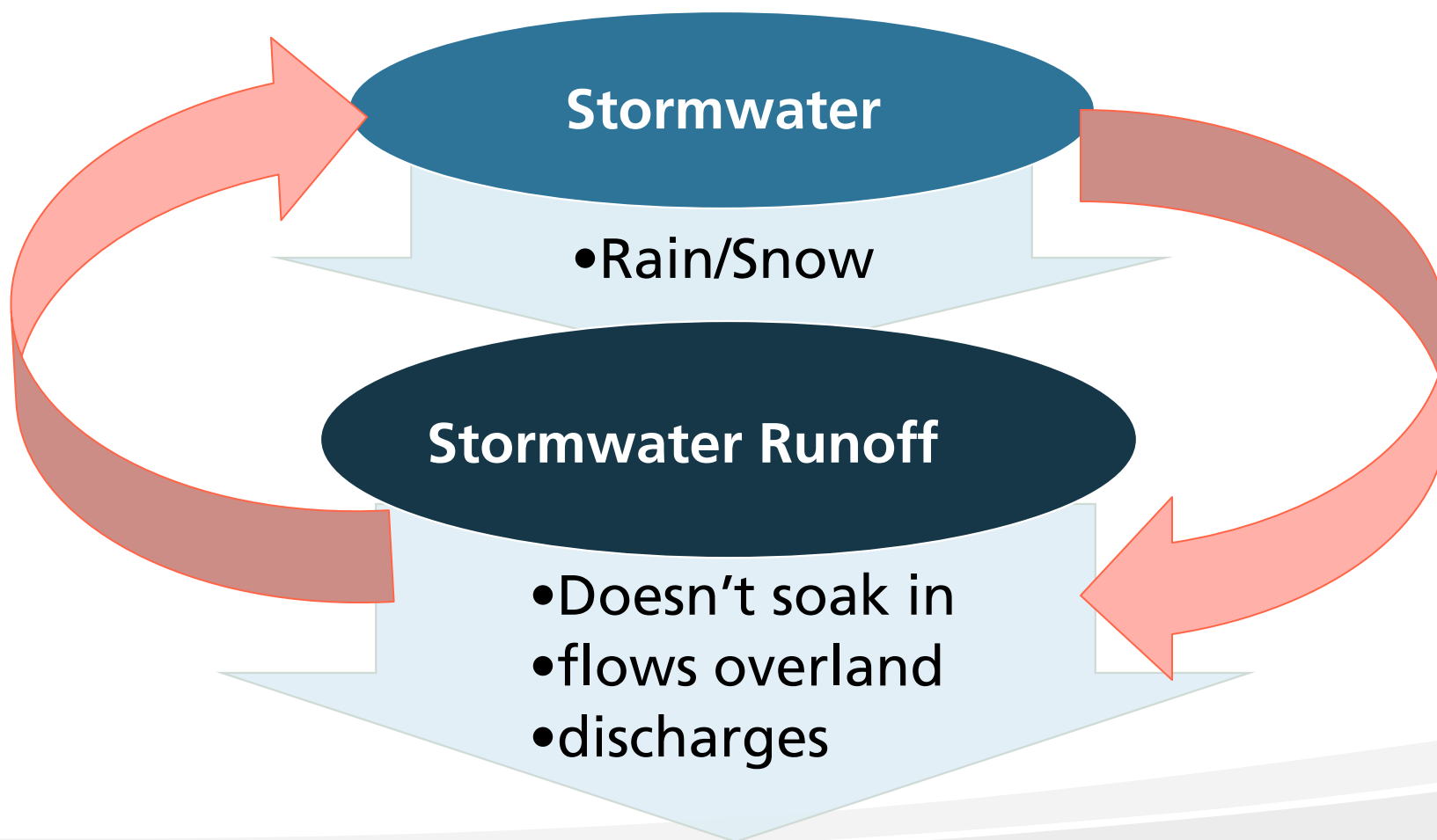
Why stormwater management matters



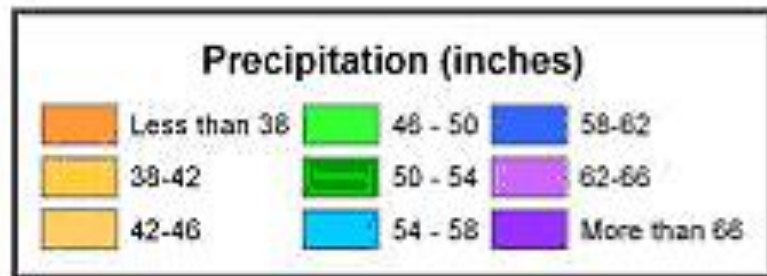
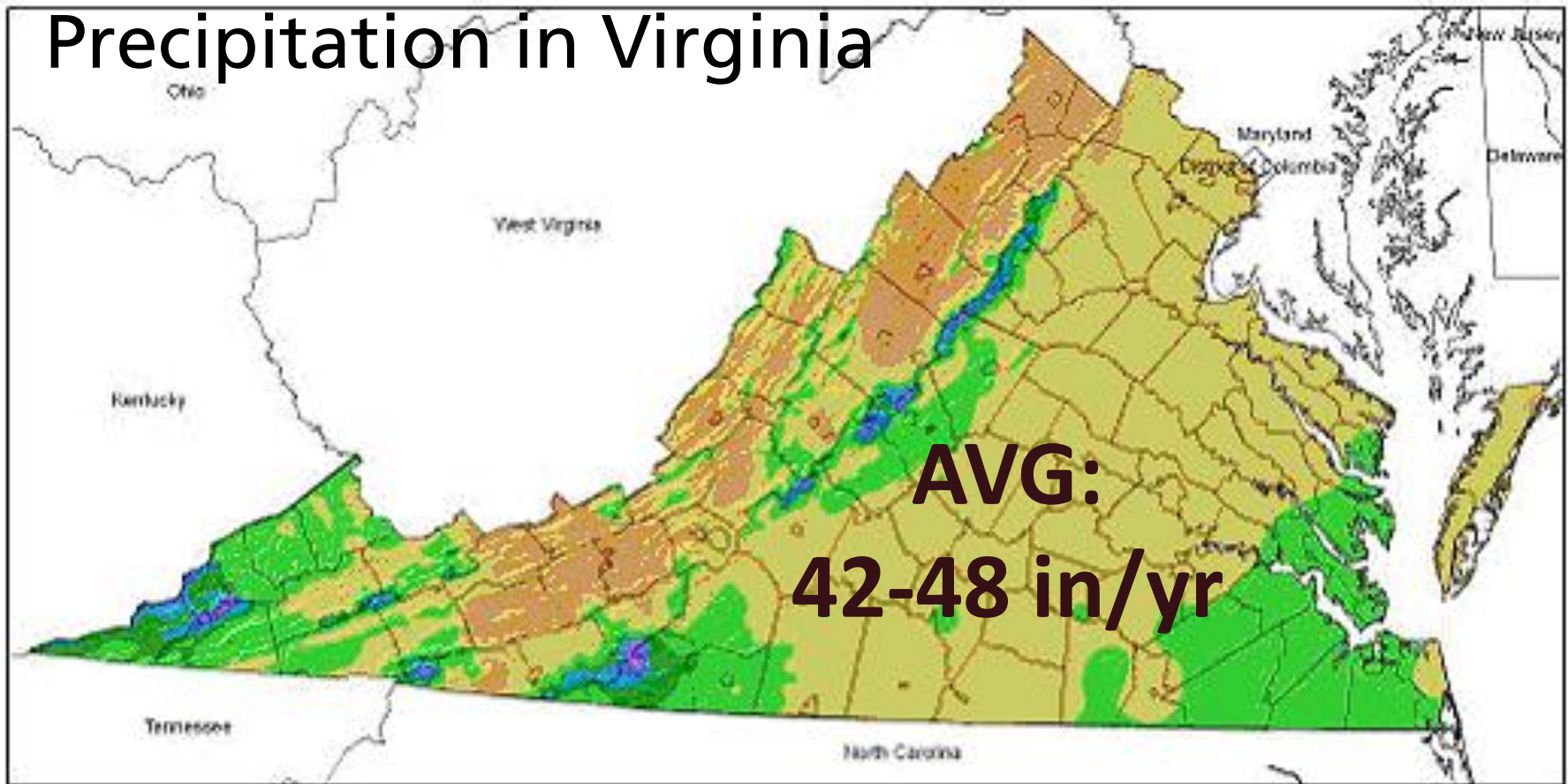
Overview



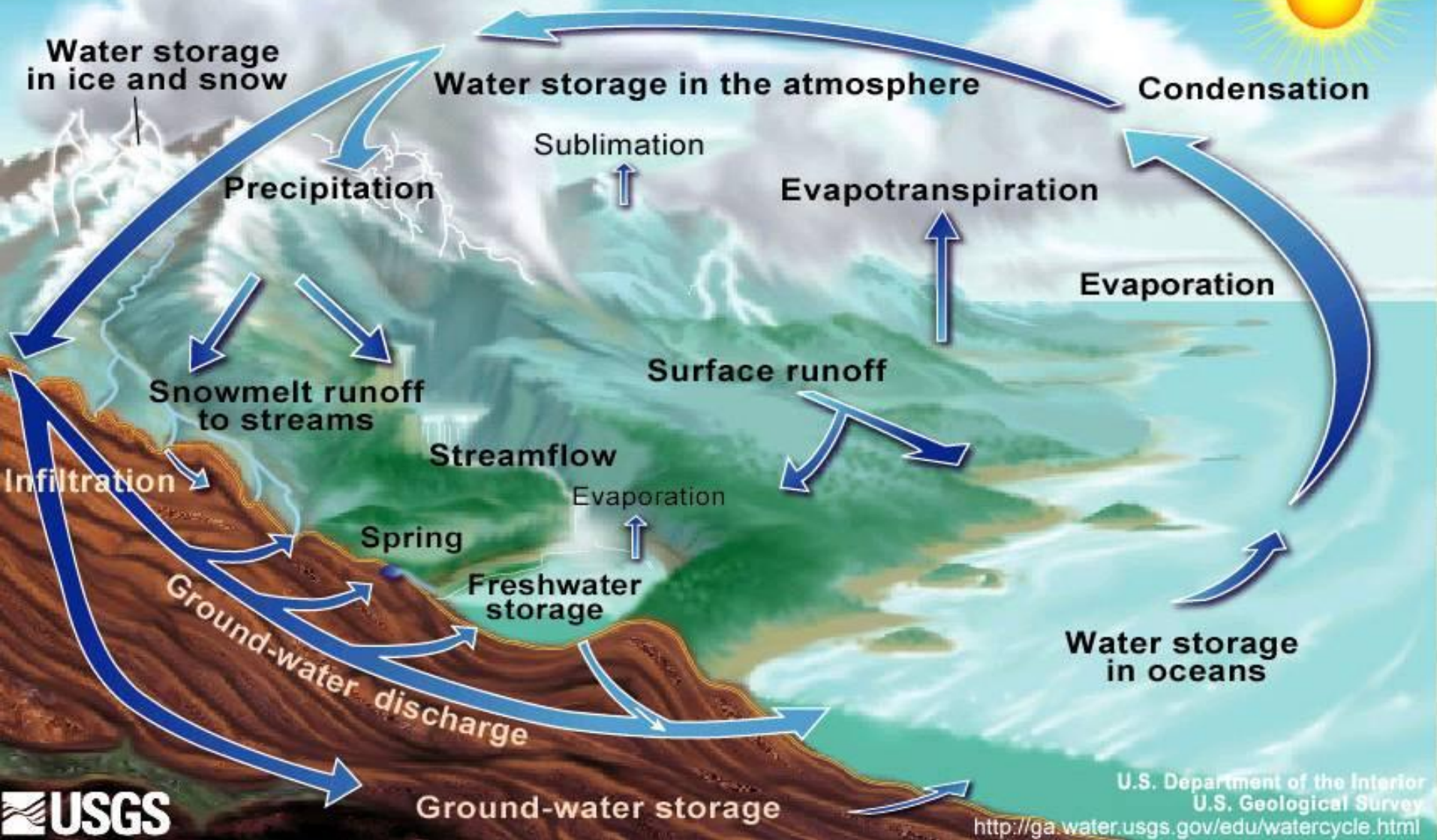
Common Definitions:



Precipitation in Virginia



The Water Cycle

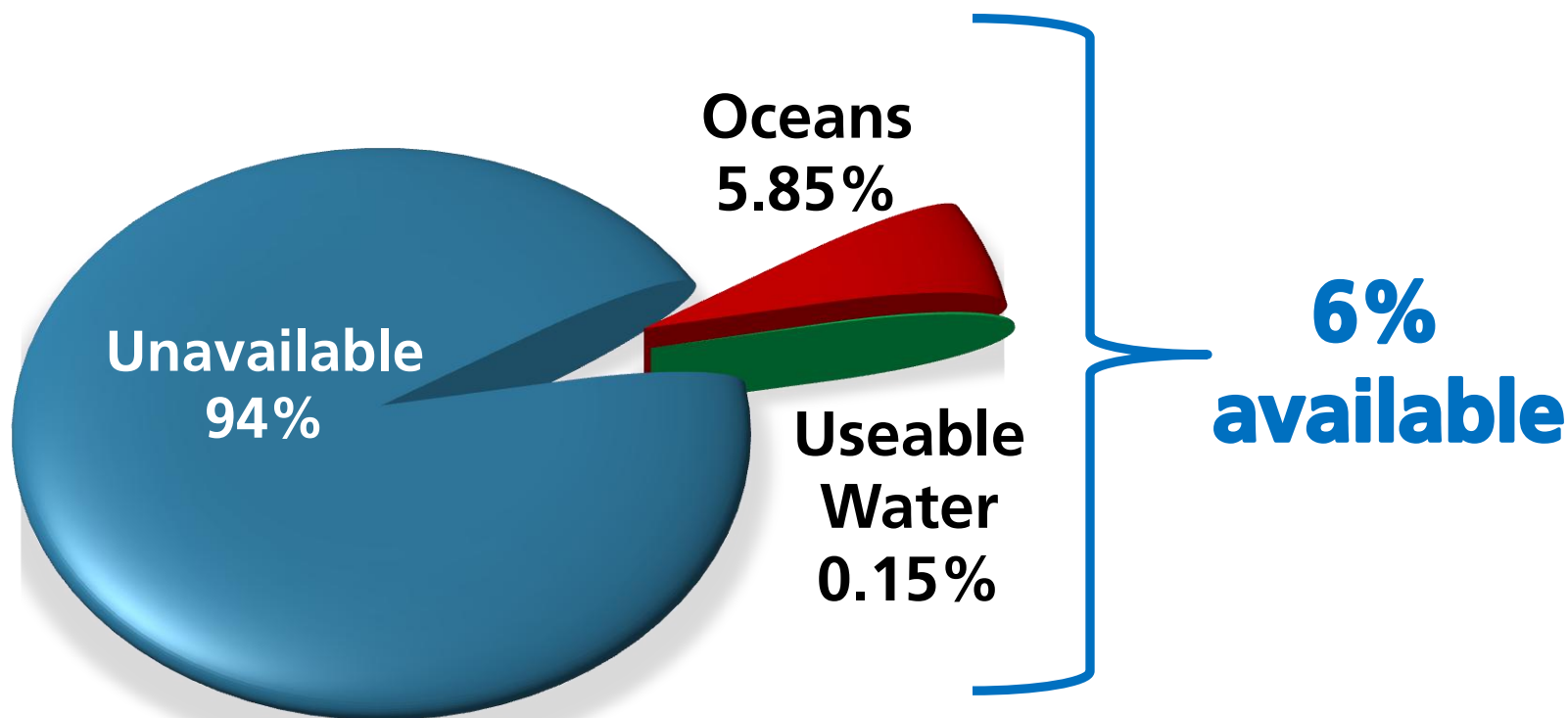




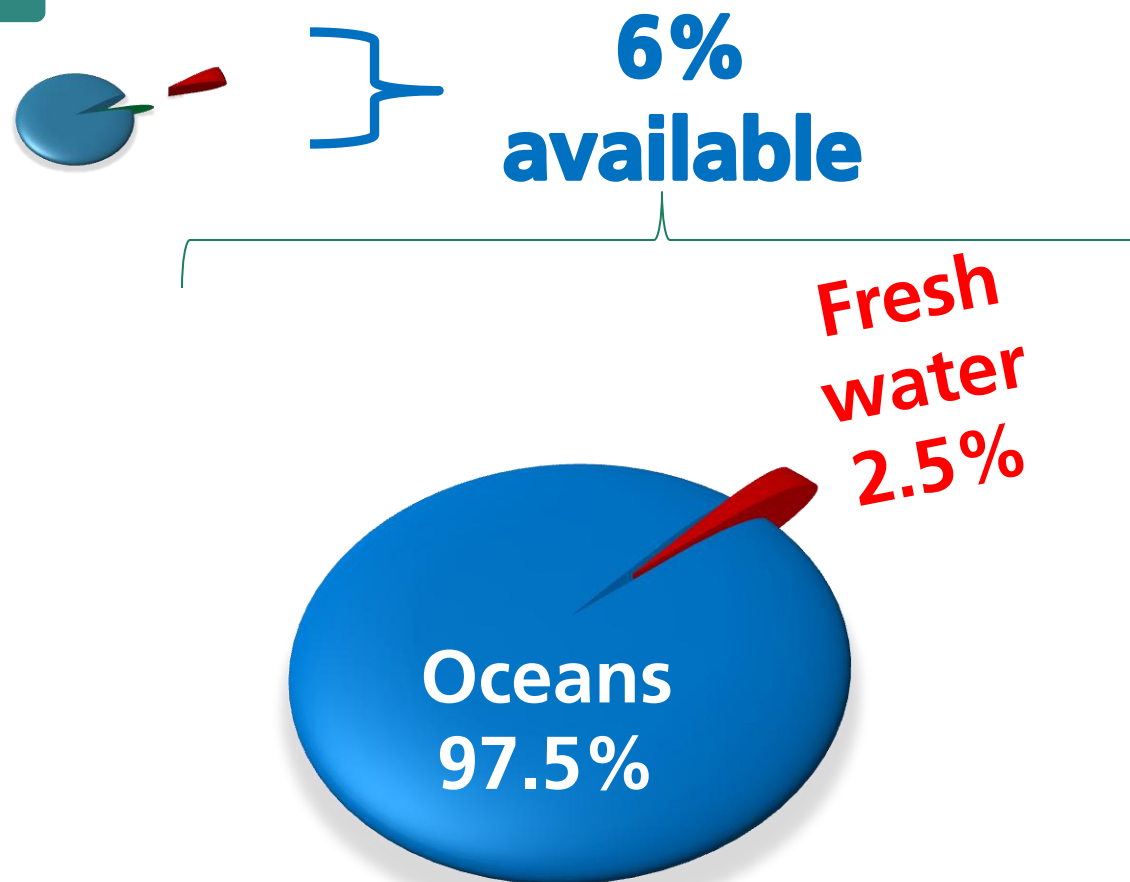
Key Points to Consider:

- only a fraction of the earth's total water is available as fresh water
- this limited availability of fresh water is critical for human health and survival
- In Virginia, projected population increases and changes in precipitation patterns could make water availability much more concerning in the future

The Water Budget

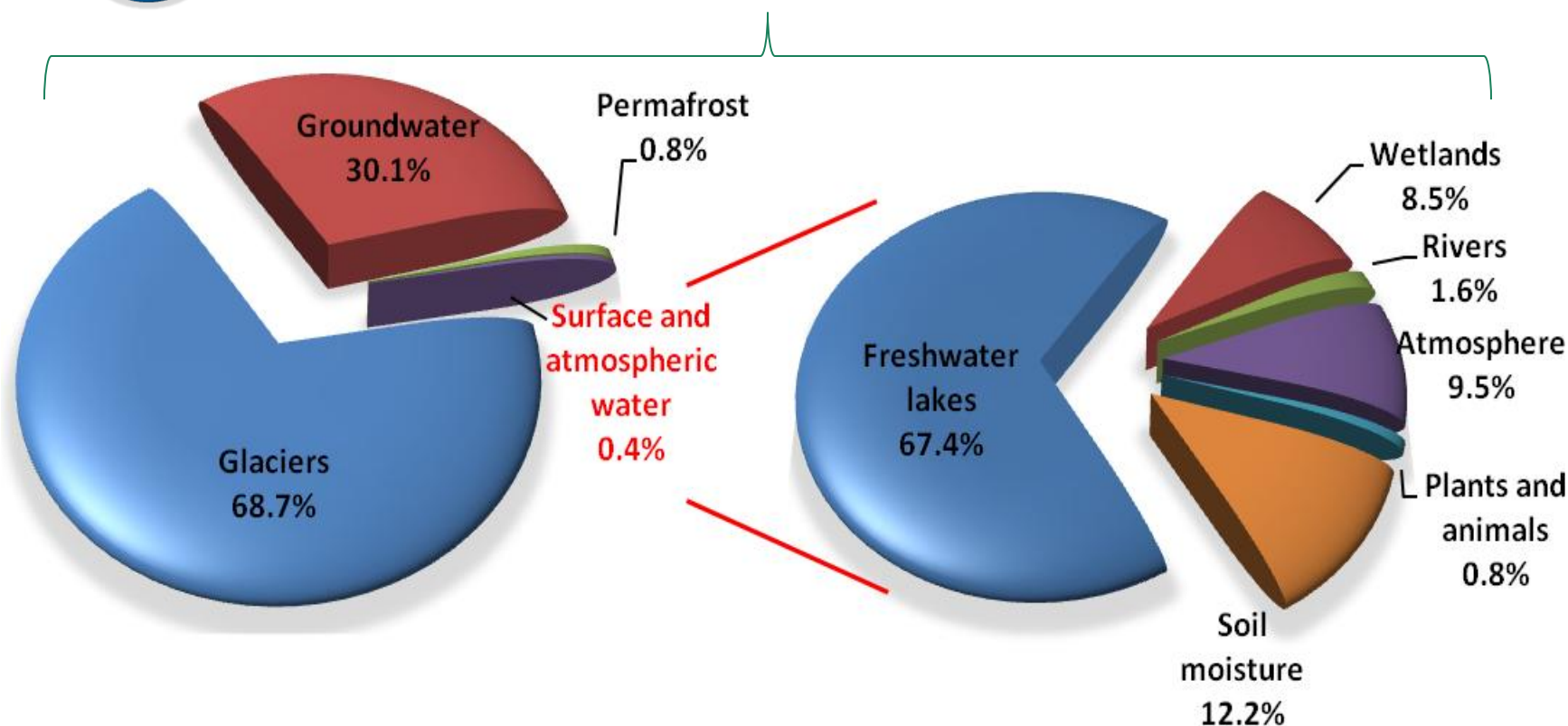


The Water Budget

PG 6

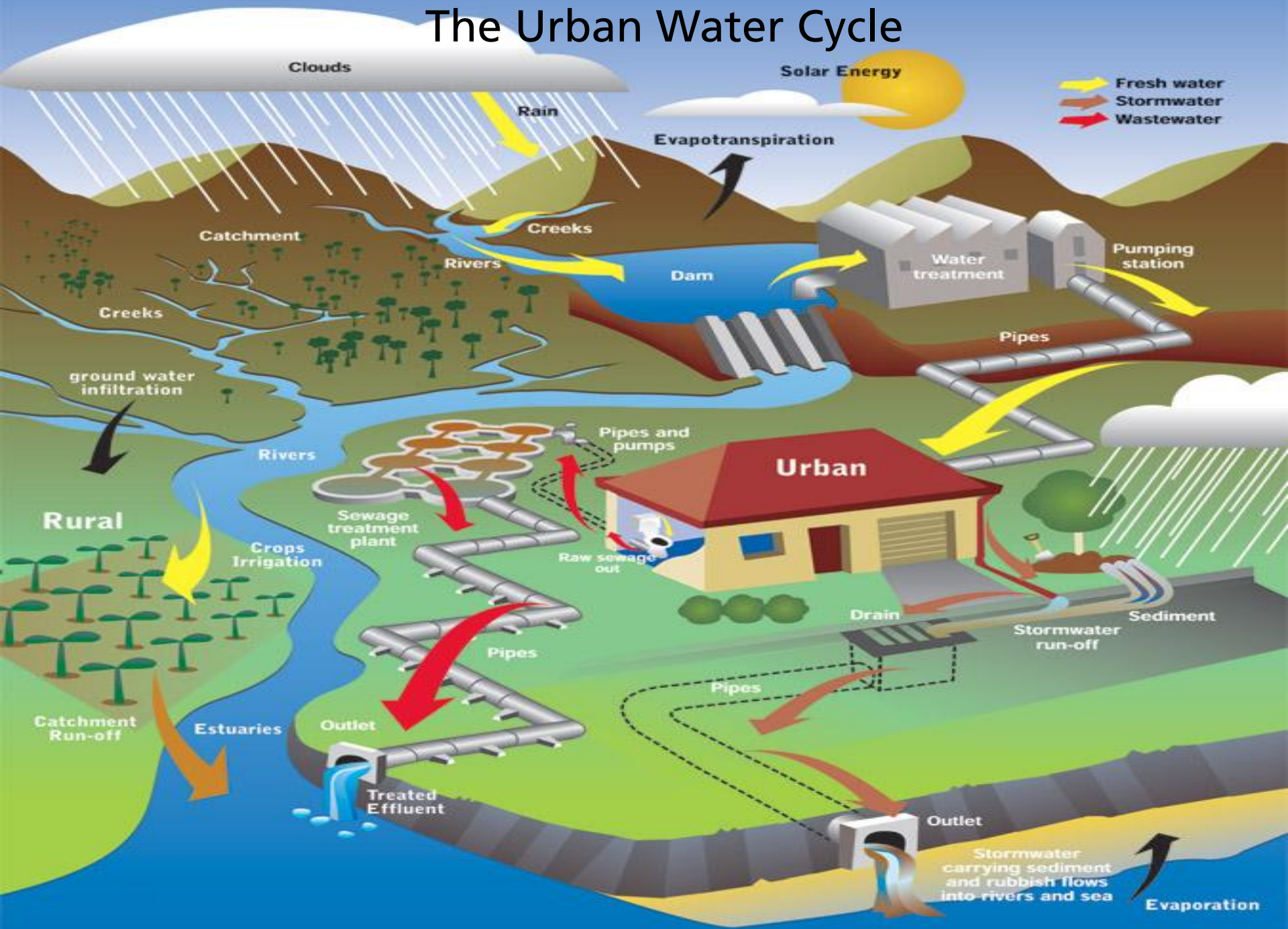
The Water Budget

**2.5% of
available water**

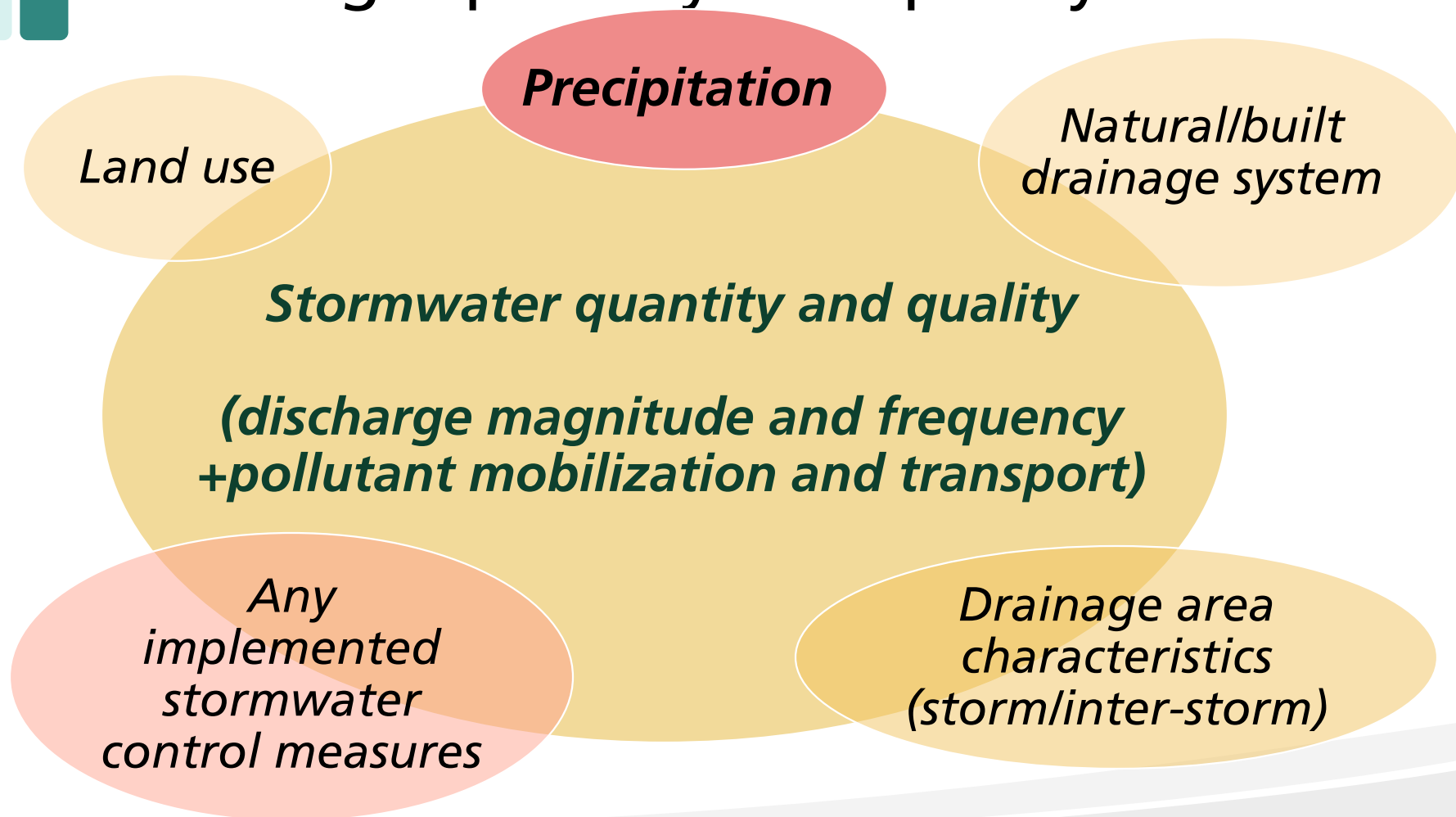


2D. DISTRIBUTION OF THE EARTH'S WATER — THE WATER BUDGET

The Urban Water Cycle



Factors that influence stormwater discharge quantity and quality:



Changes in the hydrology cycle

Module 2
PG 9

precipitation

Before

Evapo-transpiration
40-50%

20-30%
interflow

water table

groundwater
10-40%

less than 1%
surface
runoff

precipitation

After

Evapo-
transpiration
20-30%

0-30%
interflow

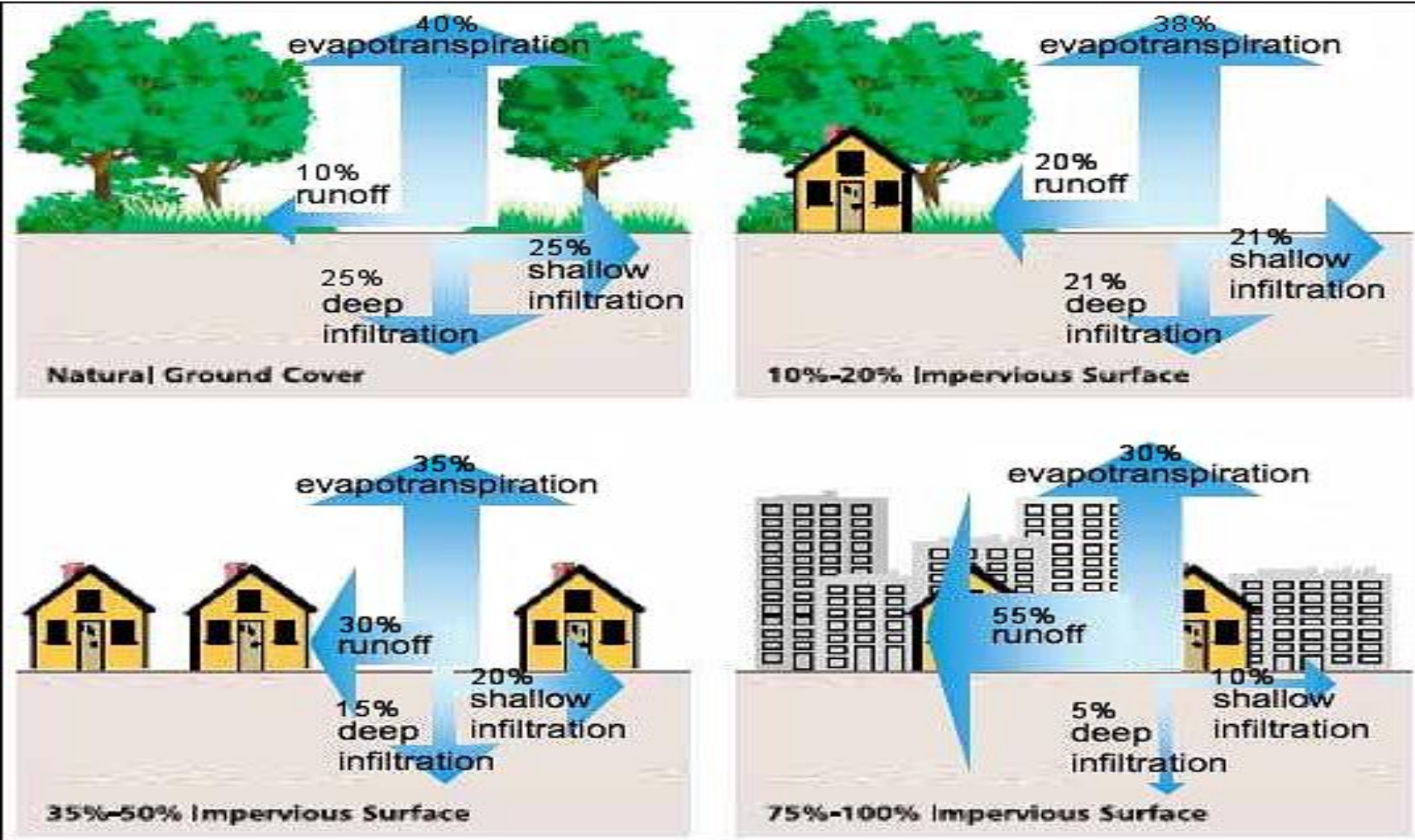
water table

groundwater
10-20%

20-30%
surface
runoff

2E. THE URBAN WATER CYCLE

Collective Impact on Hydrologic Cycle



2E. THE URBAN WATER CYCLE

Pre- and Post- Development

Module 2
PG II



2E. THE URBAN WATER CYCLE

Urban drainage systems:

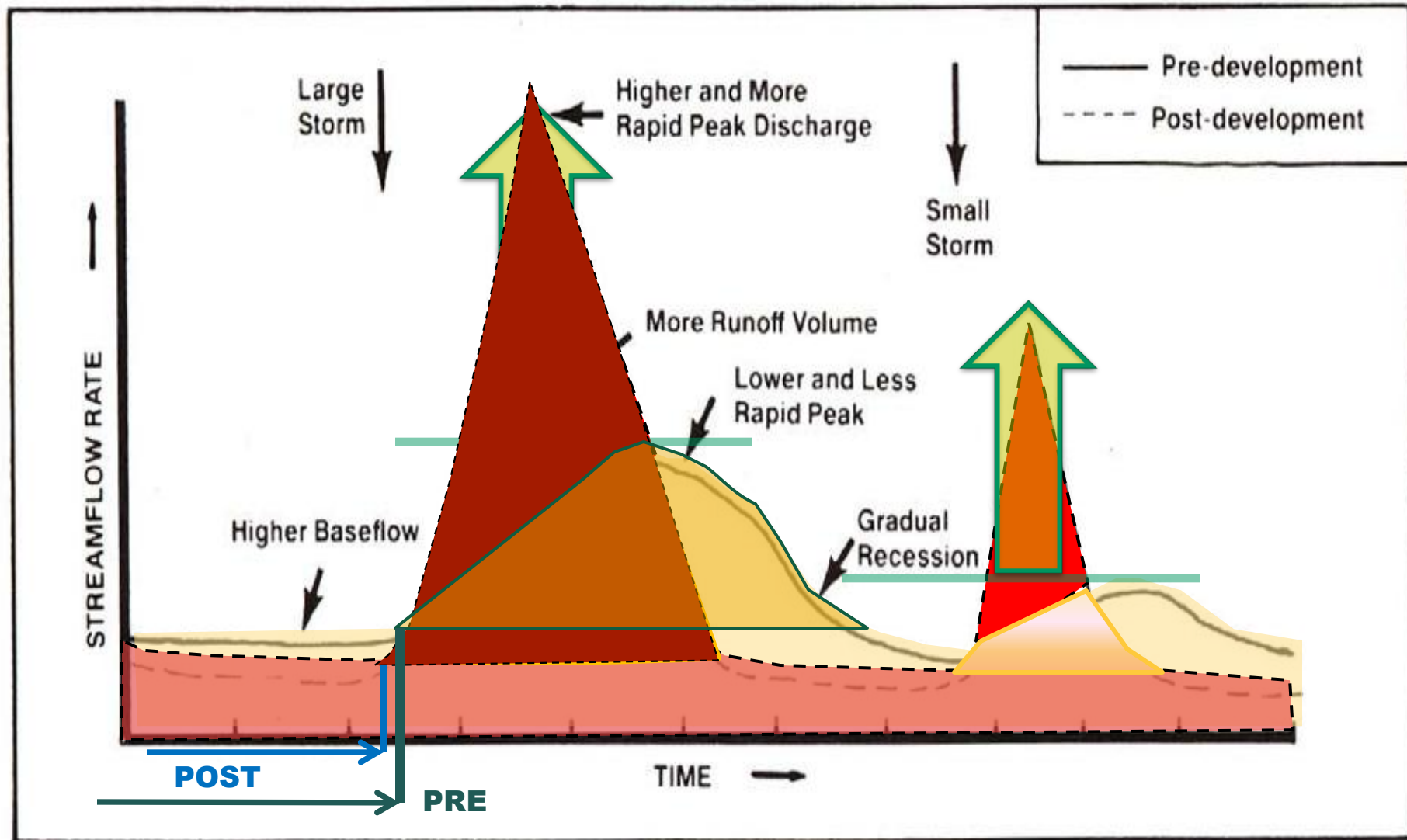
Module 2

PG II



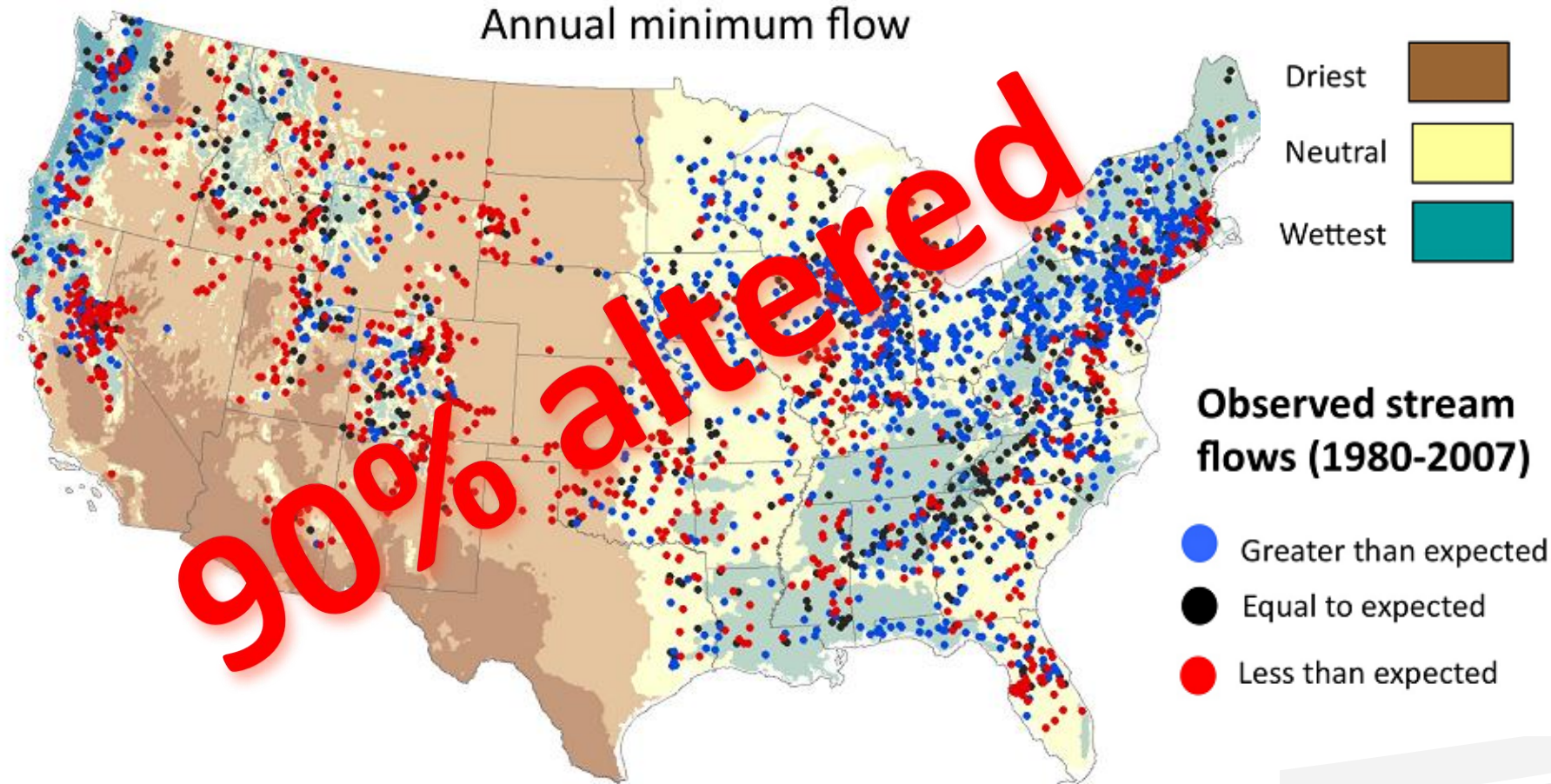
2E. THE URBAN WATER CYCLE

Stream flow changes:



Altered Stream Flow

Annual minimum flow



What climate changes are we observing? **PG 14**

- Temperatures rising
- Increase in heavy rainfall events (globally and in the U.S.)

What climate changes are we observing? **PG 14**

- Virginia
 - 25% increase in frequency of extreme precipitation events since 1948
 - Intensity and duration of drought periods also increasing

What climate changes are we observing? **PG 14**

- Virginia
 - *Consequences:*
 - Soil moisture depletion
 - Annual groundwater recharge decrease
 - Runoff from hardened dry soil surface increase

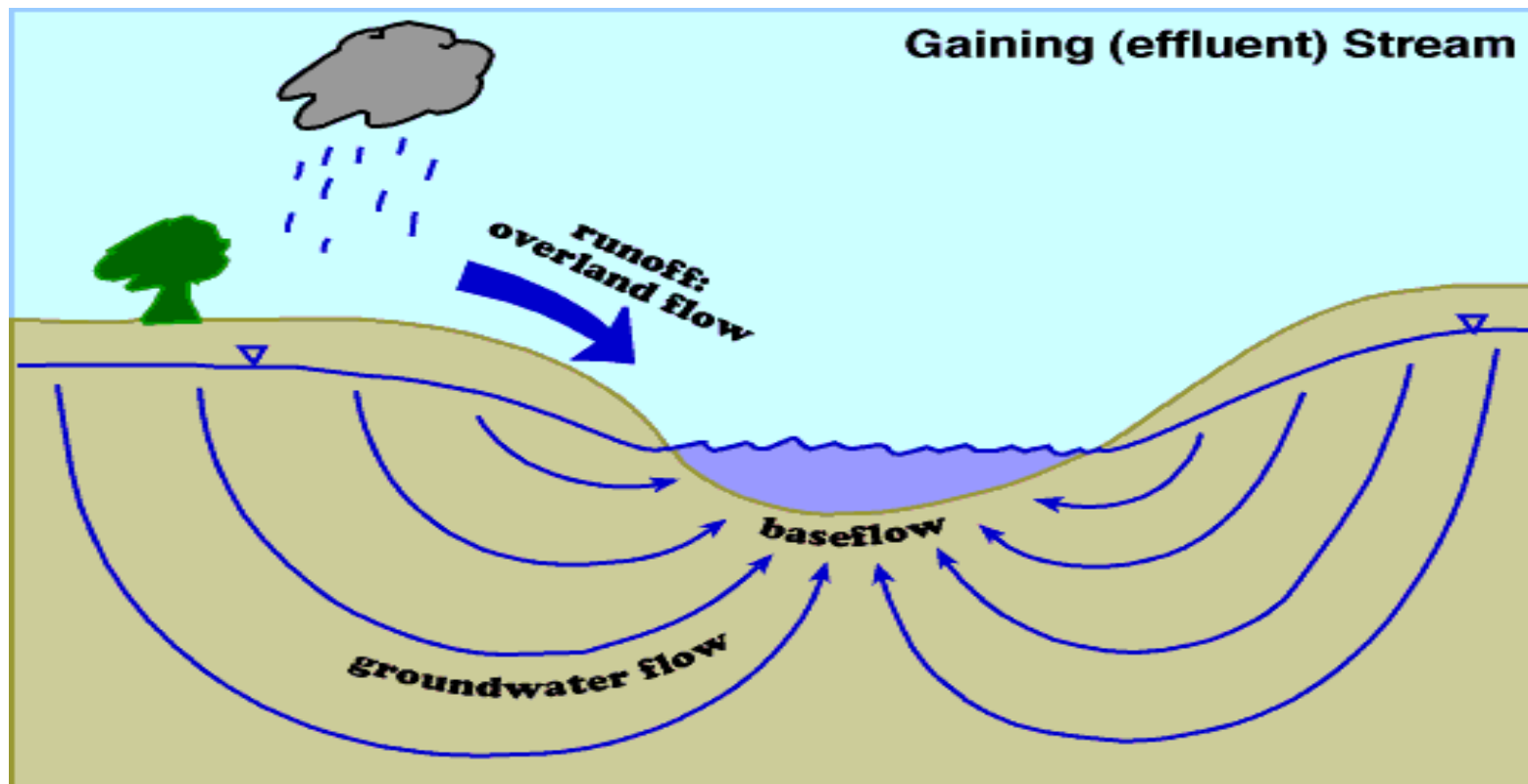


What are the simple facts?

- Greater water-carrying capacity of a warmer atmosphere (even in a localized region)
 - more water accumulates between rainfall events
 - greater likelihood of a heavy downpour
- Consequence of more frequent, intense storms
 - flooding, erosion, pollution of waterways with excess runoff, wind damage, crop damage, and other environmental and economic damage

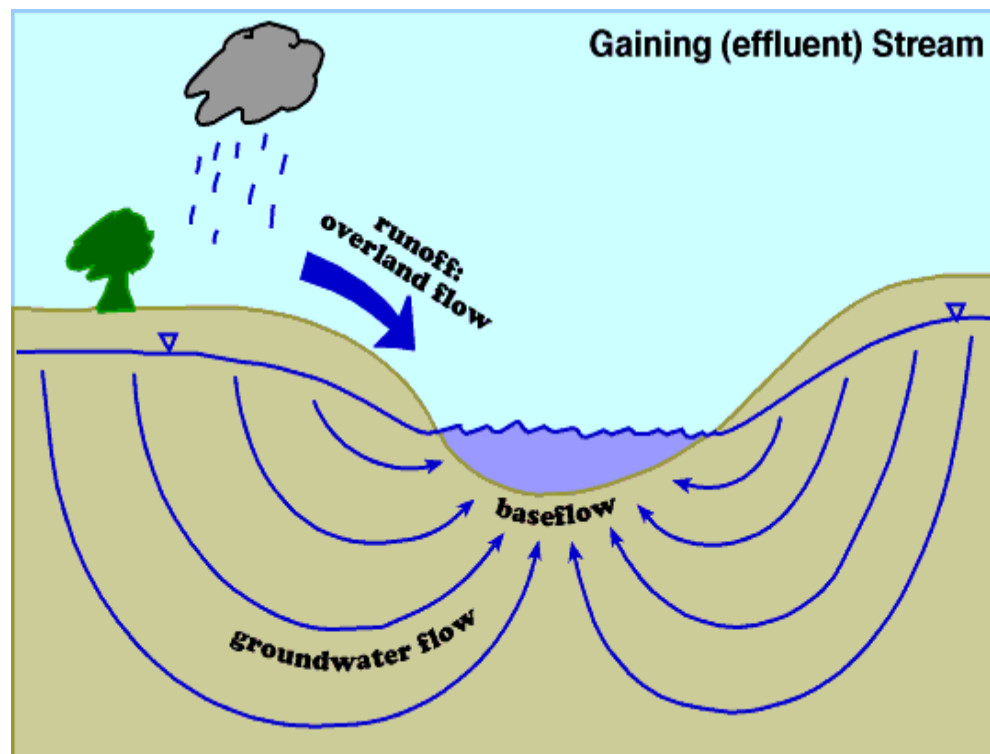
(see Module 2, Table 2-1)

What are the long term implications?



What are the long term implications?

- Less water infiltration
- Less groundwater recharge



What are the long term implications?

Extreme events and droughts:
more water level fluctuations



What are the long term implications?

More frequent bankfull flows

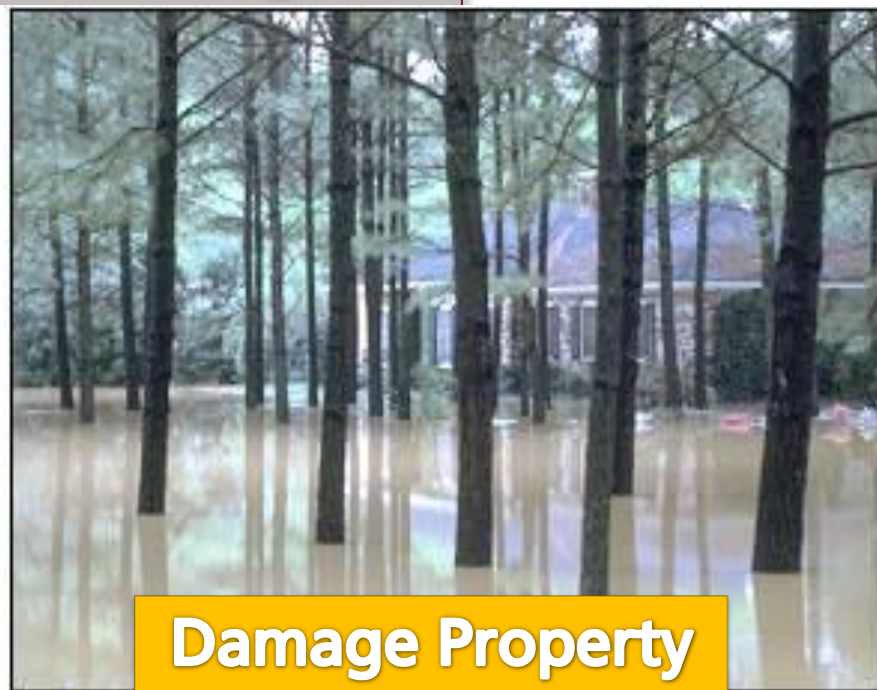


What are the long term implications?

Out-of-Bank Flooding



Endanger Human Life



Damage Property



Knowledge Check



Rainfall in Virginia averages between _____ and _____ per year?

Answer: 42 - 48 inches per year

Knowledge Check



Which of the following represent human influences on the natural water cycle:

- A. Groundwater withdrawal
- B. Rainfall capture in cisterns for dry period usage
- C. Diverting stormwater runoff from steep slopes
- D. Evaporation of water from ocean surfaces to the atmosphere.
- E. None of the above.

Answer: A, B, and C

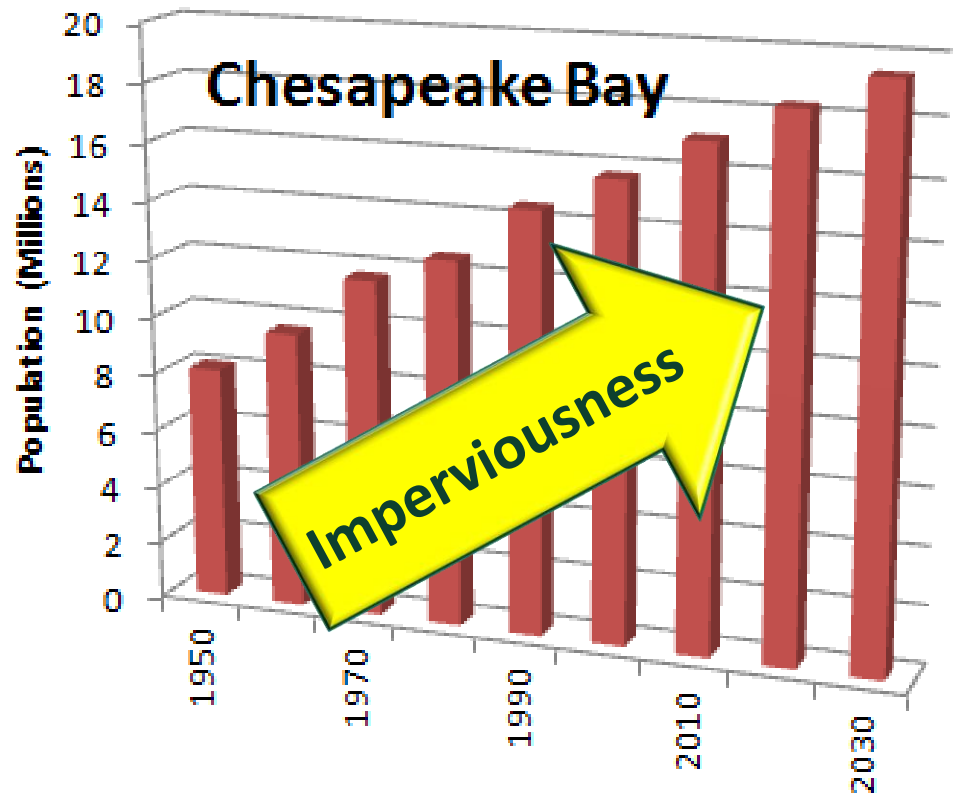


Knowledge Check



The frequency of extreme precipitation events in Virginia since 1948 has increased by what percent?

Answer: 25%



"We're waiting for the city to come to us..."

Ideal Natural Stream



Urban Stream Syndrome




USGS, 2012



How does it happen and what are the consequences?

I. Changes to the land surface (topography, *impervious cover*, vegetation)



I. Changes to the land surface (topography, *impervious cover*, vegetation)

Loss or change of vegetation

Soil compaction

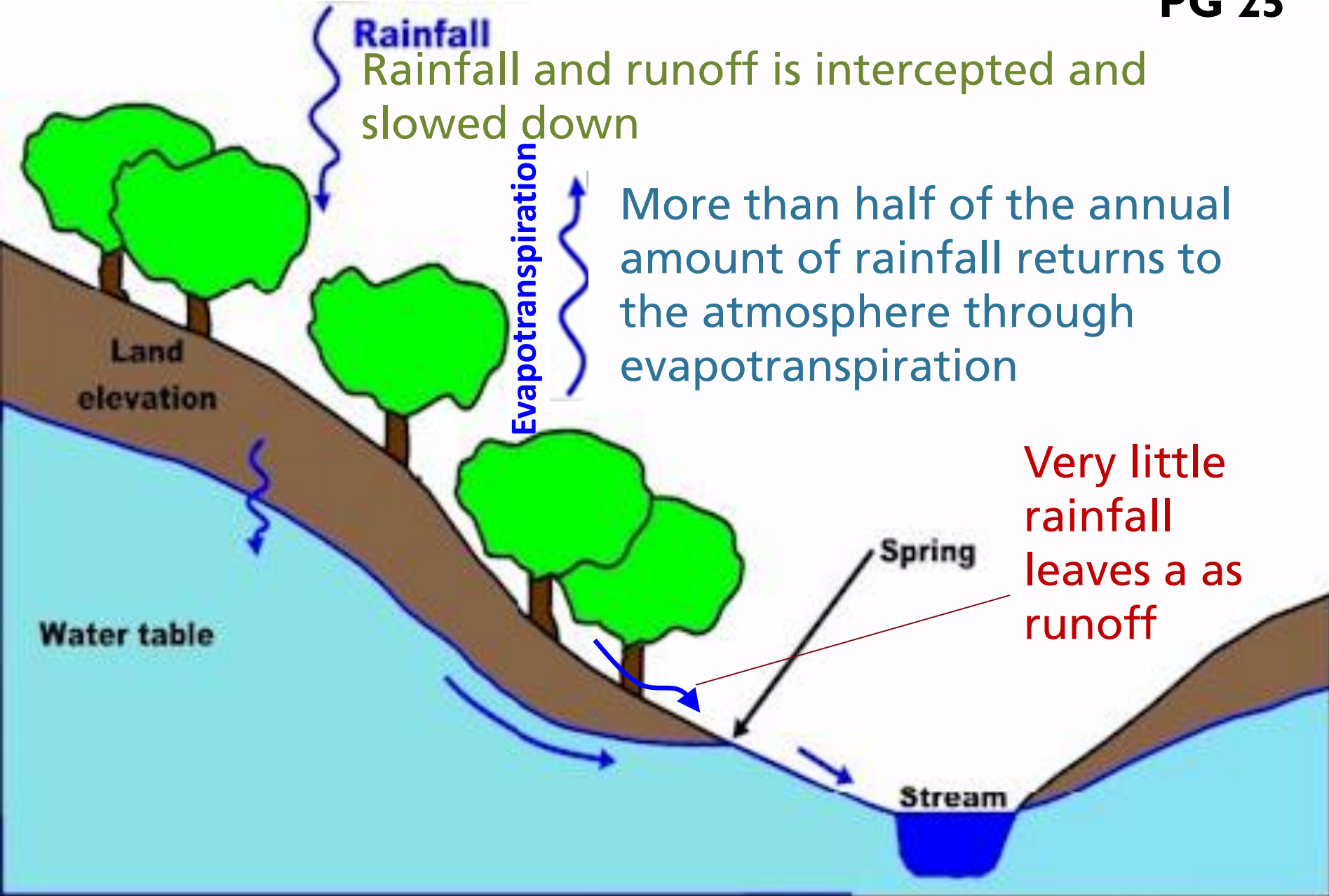
Reduced groundwater recharge and stream base flow

Increased imperviousness of land surface

Loss or change of vegetation

Module 2

PG 25



Loss or change of vegetation

Removing natural vegetation reduces evapotranspiration, infiltration and increases the amount of stormwater runoff

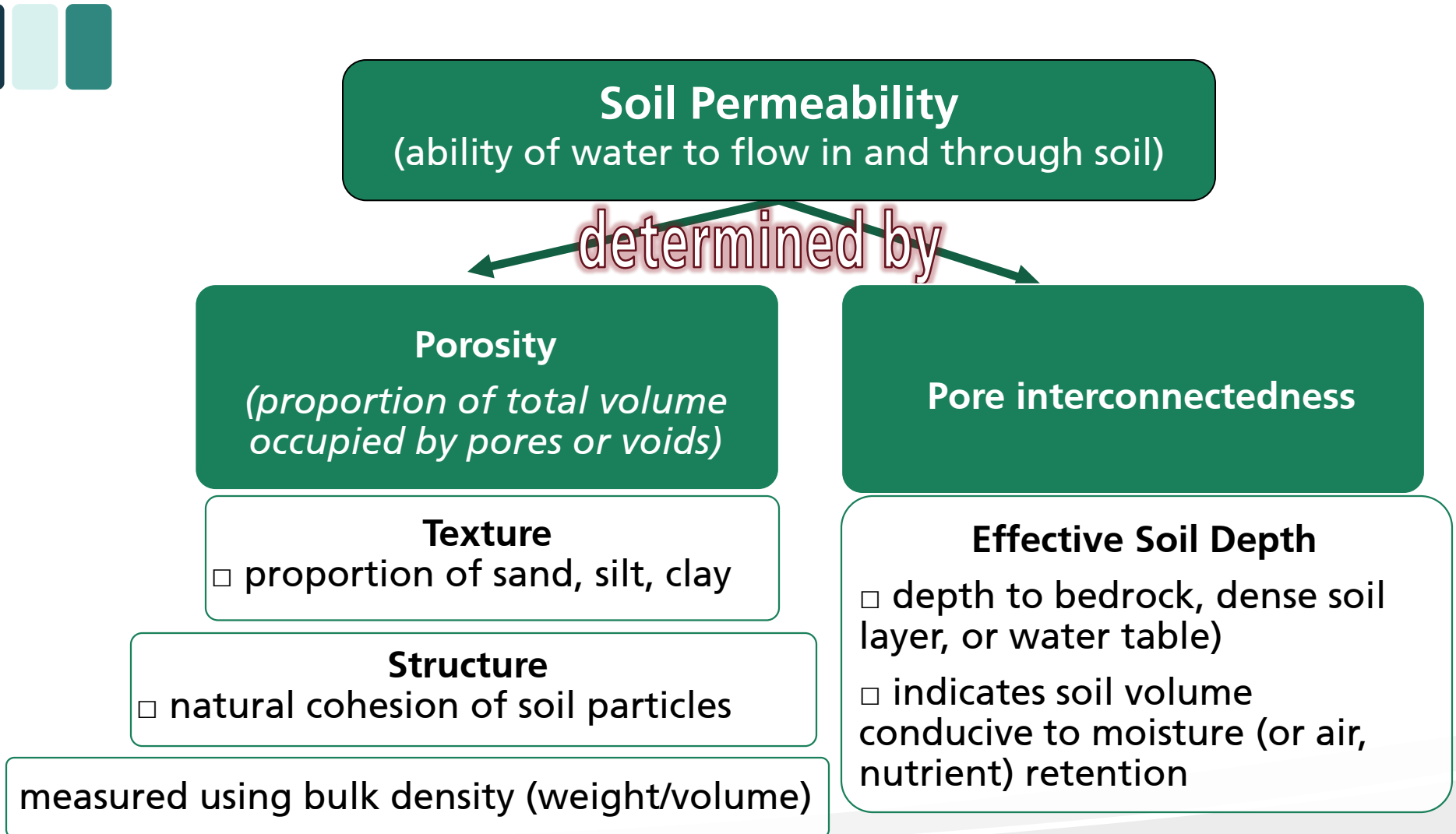


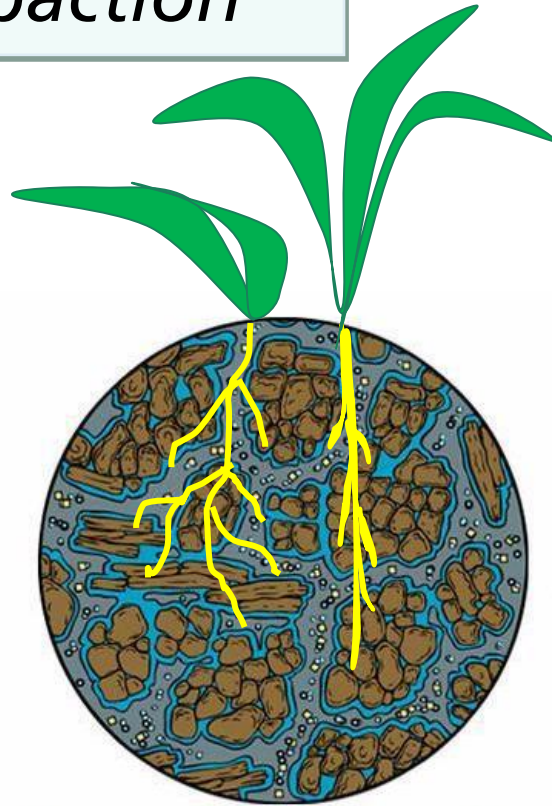
Loss or change of vegetation

75% Turf cover in the watershed has tripled in the last 30 years (acres)

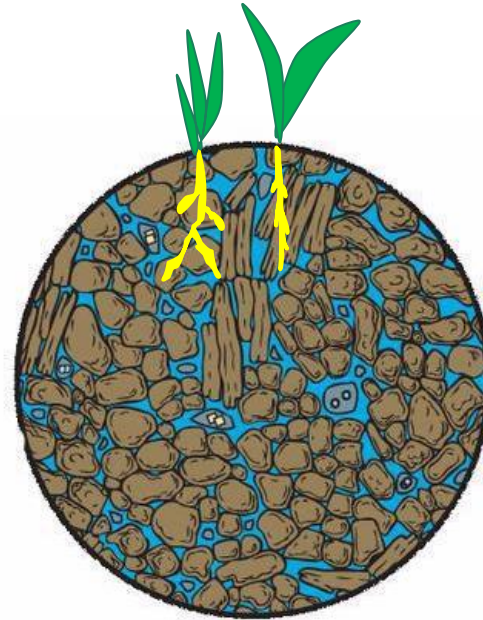


Our compacted lawns
roughly produce an
extra storm runoff
flow of 1,244 cfs *each*
day to the
Chesapeake Bay





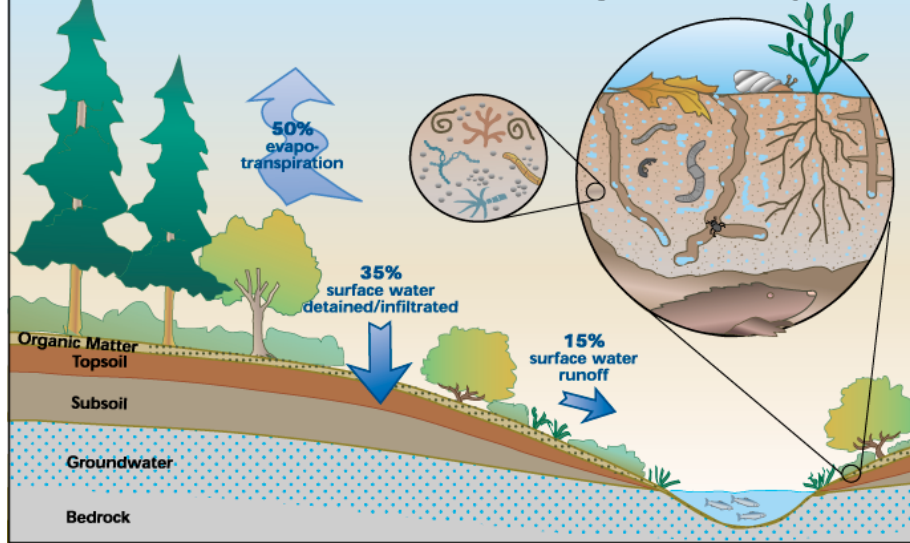
Lower bulk density
Lower weight
More pore space



Higher bulk density
Higher weight
Less pore space

(Source: Adapted from International Society of Arboriculture, Bugwood.org)

Before land disturbing activity

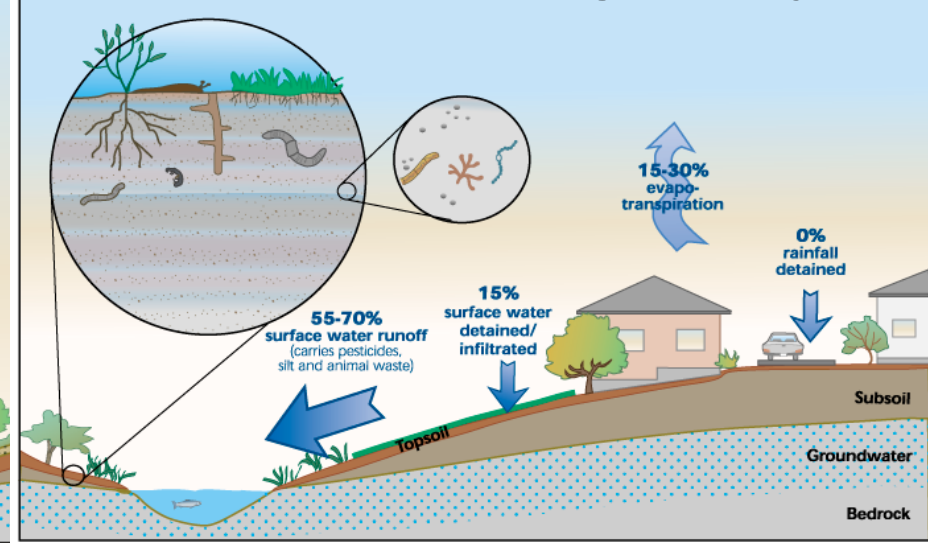


Thick topsoil

Organic matter

Soil structure and texture
intact

After land disturbing activity

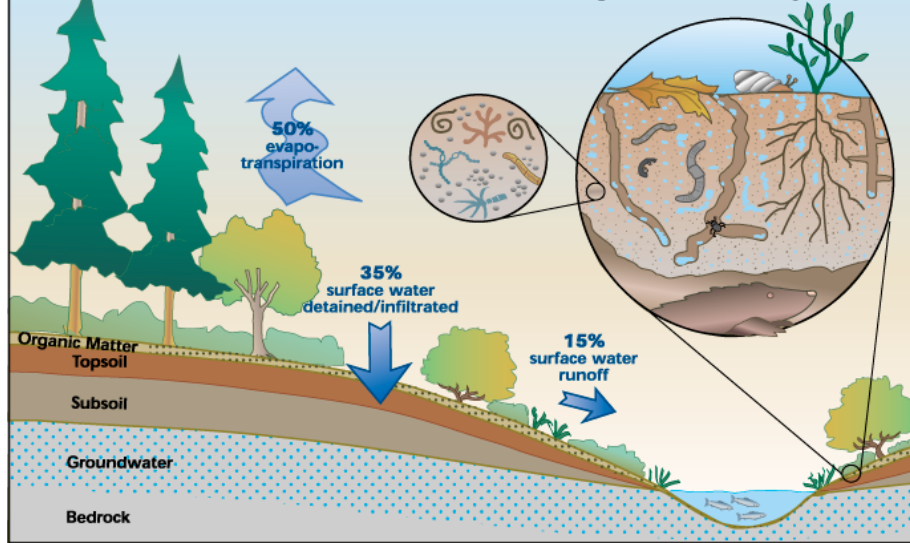


Thin topsoil or none

Loss of organic matter

Compacted soil

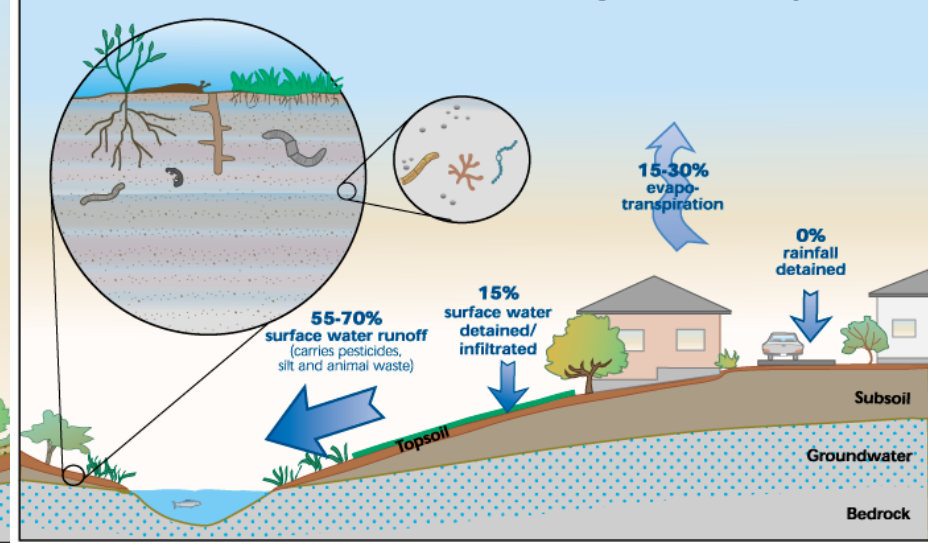
Before land disturbing activity



Good soil porosity

Good soil permeability

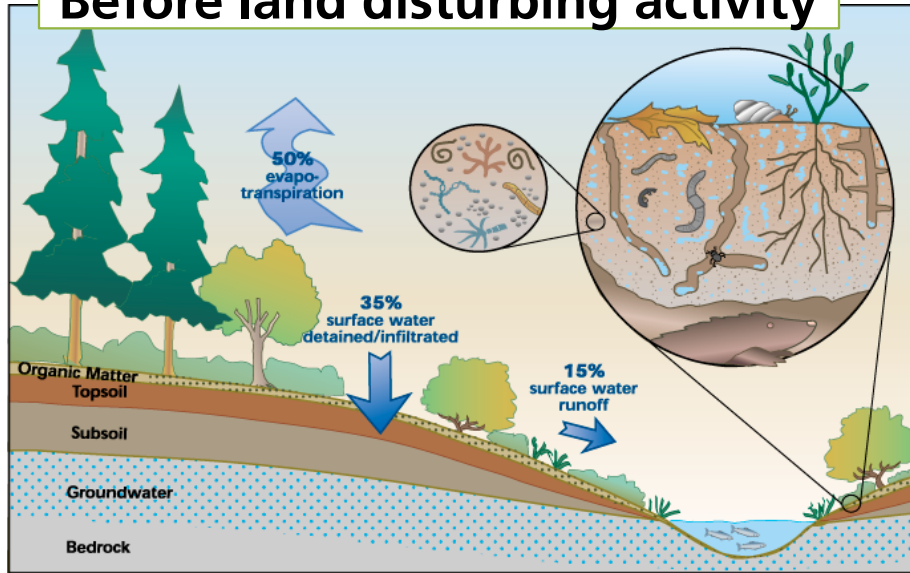
After land disturbing activity



Decreased soil porosity

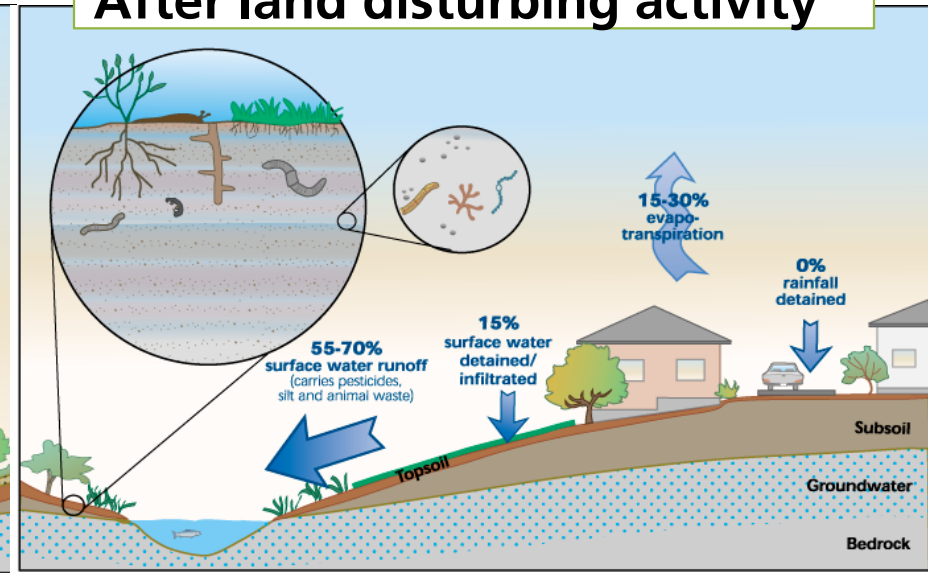
Decreased soil permeability

Before land disturbing activity



Very little surface runoff

After land disturbing activity



More surface runoff



Reduced Groundwater Recharge *Reduced Stream Base Flow*

Module 2
PG 33

Perennial streams – continuous baseflow

More runoff = less groundwater recharge

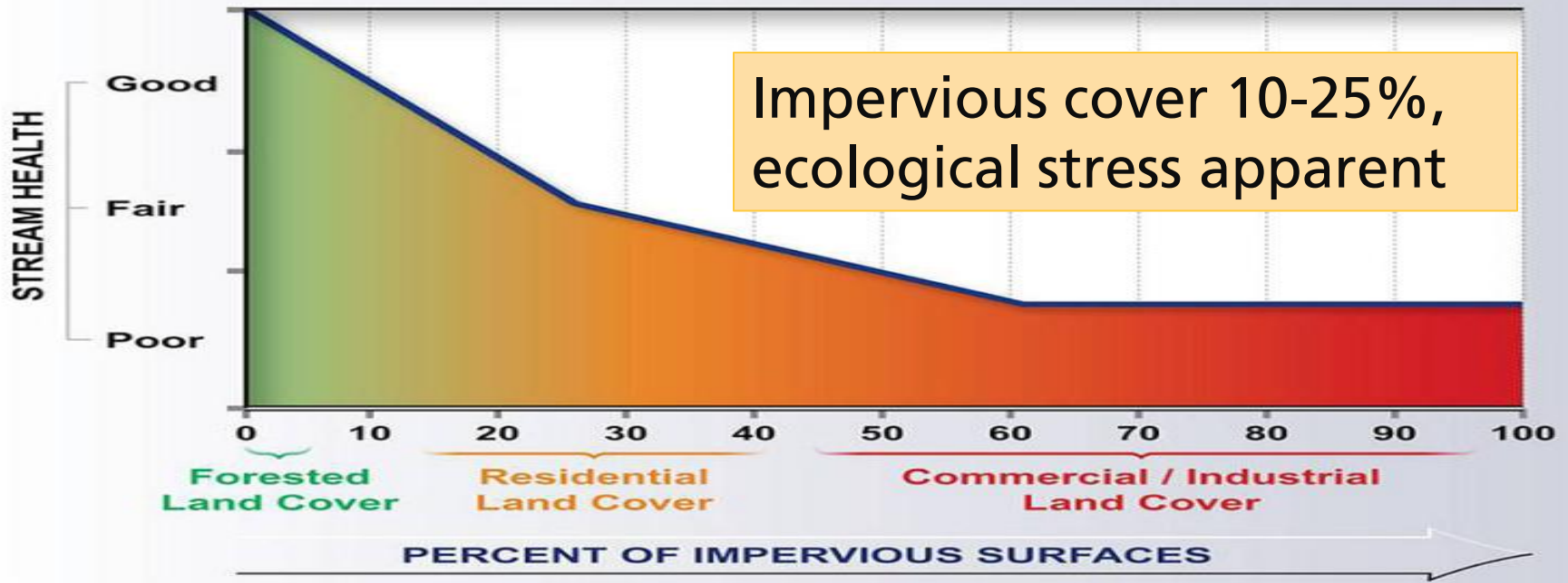
Flow may diminish or even cease

**Droughts – reduced baseflow can affect stream
water quality**

Reduced dissolved oxygen

- stress aquatic life**
- chemically release sediment-bound pollutants**

Impervious Surface & Stream Health




>25%, stream stability reduced

- Habitat lost
- Water quality degraded
- Biological diversity diminished



How does it happen and what are the consequences?

II. Stream channel and flood plain impacts



Impacts of altered stormwater runoff (*greater volumes more often; higher flow rates*):

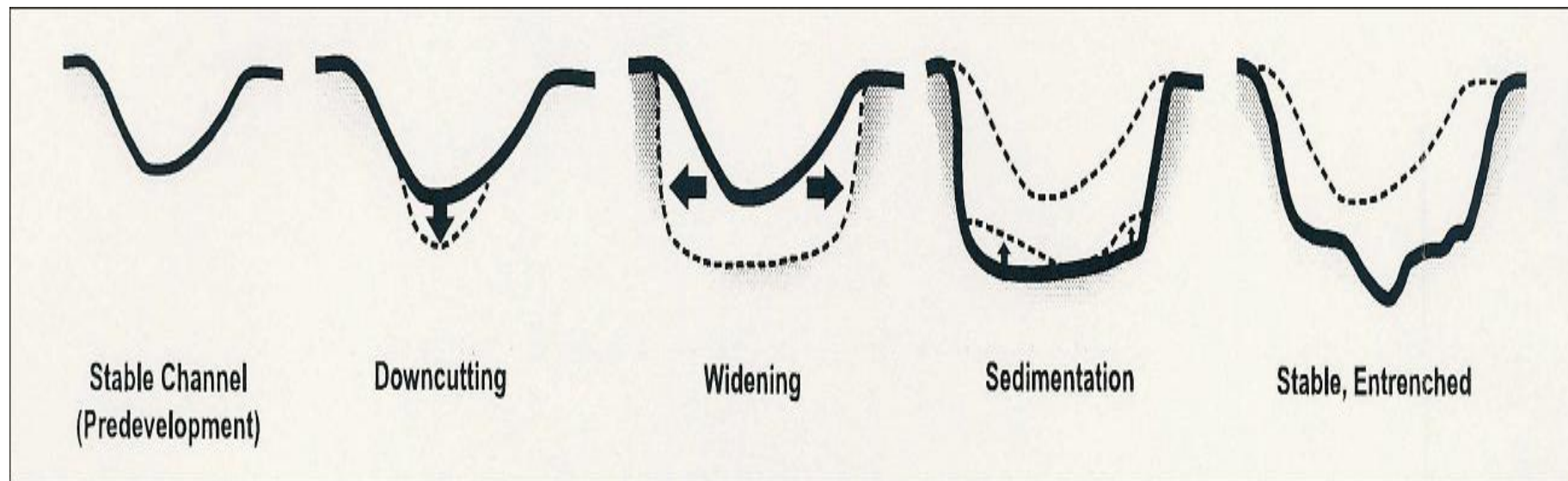
Altered stream flow

Channel erosion, widening and downcutting

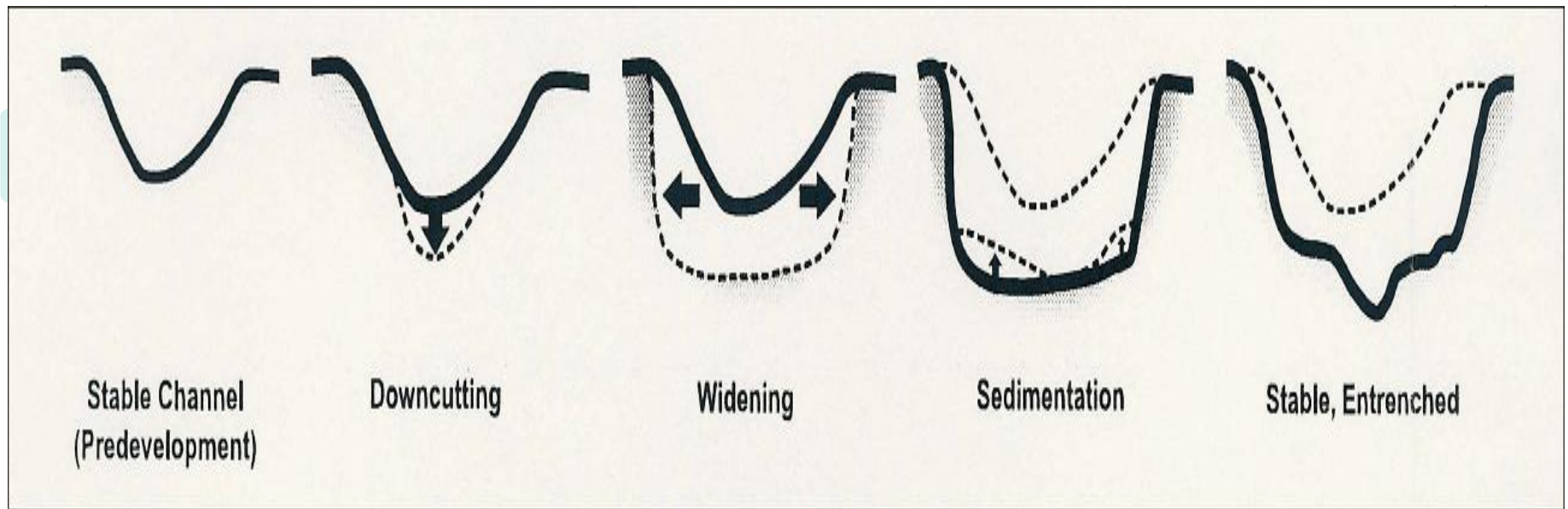
Increased frequency of bank-full and over-bank floods

Floodplain expansion

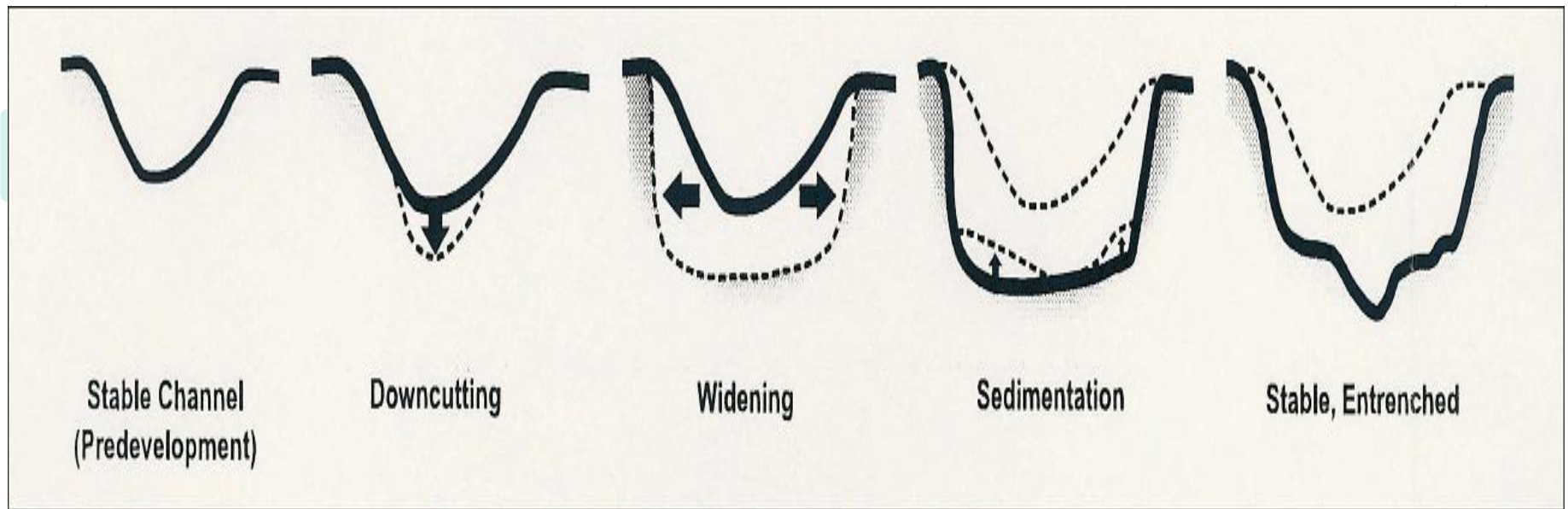
- Annual, seasonal cycles of flows shape ecological processes
 - Minimum flows maintain suitable water conditions for aquatic life
 - High flows replenish floodplains and flush out naturally accumulated sediment
 - Flows altered by land/water management activities
 - 42% of U.S.'s wadeable stream segments in poor biological condition



- There is link between altered stream channels and land development
- Natural shape, form, and stability of stream channels are influenced by increased runoff



- Downstream channels enlarge through widening and stream bank erosion to convey increased runoff volumes and higher stream flows
- Increased runoff volume can turn small meandering streams into highly eroded, deeply incised stream channels



- Increased runoff undercuts and scours lower parts of streambank
- Causes steeper banks to slump and collapse during larger storms
- Higher flow velocities further increase streambank erosion rates

In a developing watershed:

Module 2

PG 41



- Greater flows, more often, for longer duration, erode stream banks and cut down channel bottom
- Stream channel geometry configures for these larger flows

In a developing watershed:



- Increased elevation
- Stream path unstable
- Leads to increased velocities and triggers further channel erosion both upstream and downstream



How does it happen and what are the consequences?

III. Habitat and Ecological Impacts

Degradation of Habitat Structure

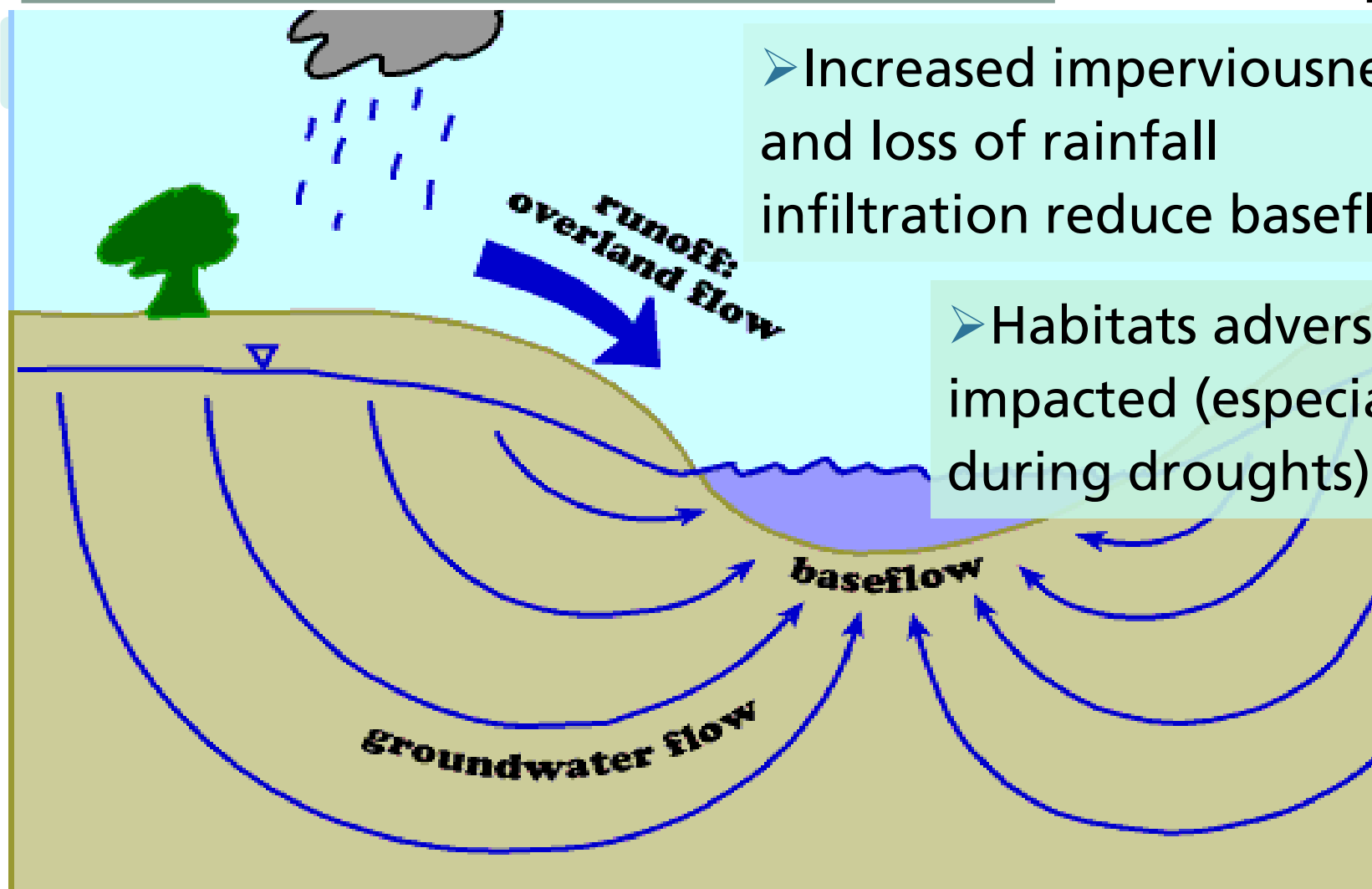


- Effects occur at many levels in an aquatic community
- Higher faster flows scour channels and can wash away entire biological communities
- Sediment deposition from runoff and eroding stream bank bury stream beds (and benthic habitats)

Loss of Pool-Riffle Structure



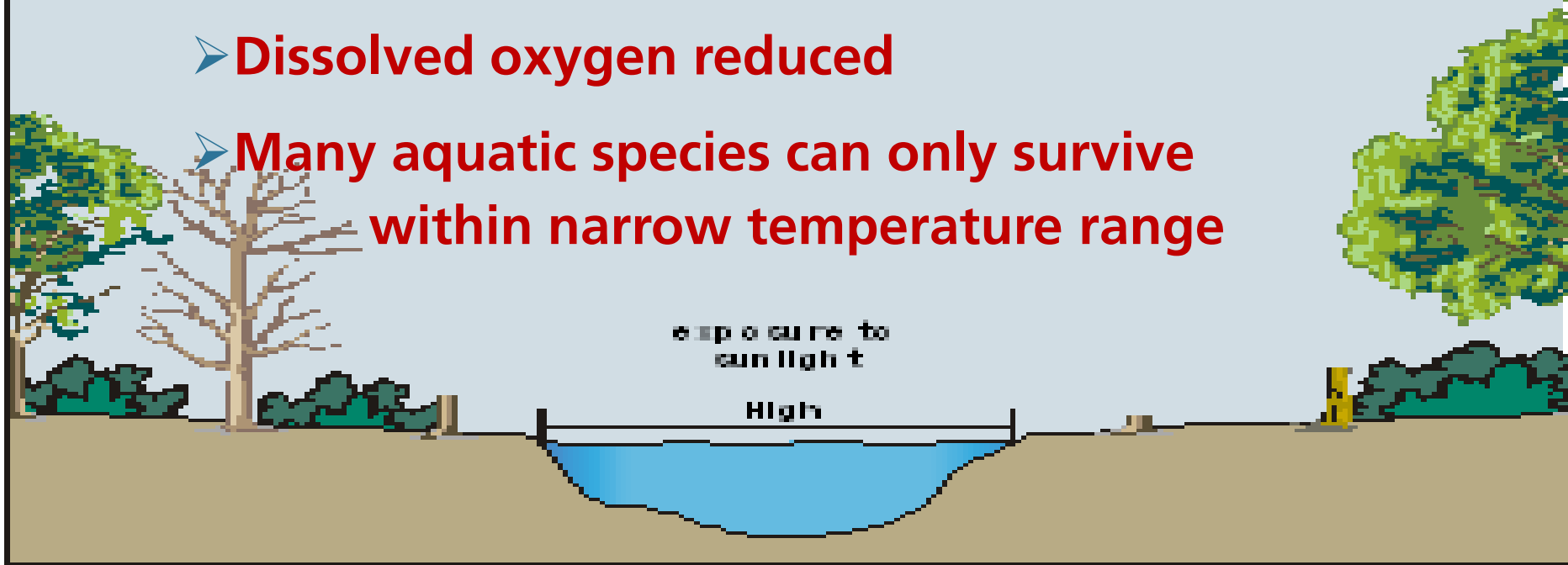
- Pools and riffles commonly found in natural meandering streams provide valuable habitat for aquatic life
- Increased flows and sediment loads replace pools and riffles with wider, more uniform streambeds and aquatic habitats
- Declined diversity and abundance of aquatic organisms



➤ Increased imperviousness and loss of rainfall infiltration reduce baseflows

➤ Habitats adversely impacted (especially during droughts)

- Runoff from warm impervious areas, storage impoundments
- Loss of shading with loss of riparian vegetation
- Dissolved oxygen reduced
- Many aquatic species can only survive within narrow temperature range



Decline in Abundance, Richness and Biodiversity of Stream Community



- Less desirable species begin to replace desirable species
- Number and variety (diversity) of organisms are reduced
- Loss of sensitive species (eg. Trout replaced by carp)



Knowledge Check



Ecological stress becomes apparent when impervious cover in a watershed reaches between:

- A. 40-50%
- B. 30-40%
- C. 20-30 acres
- D. 10-25%



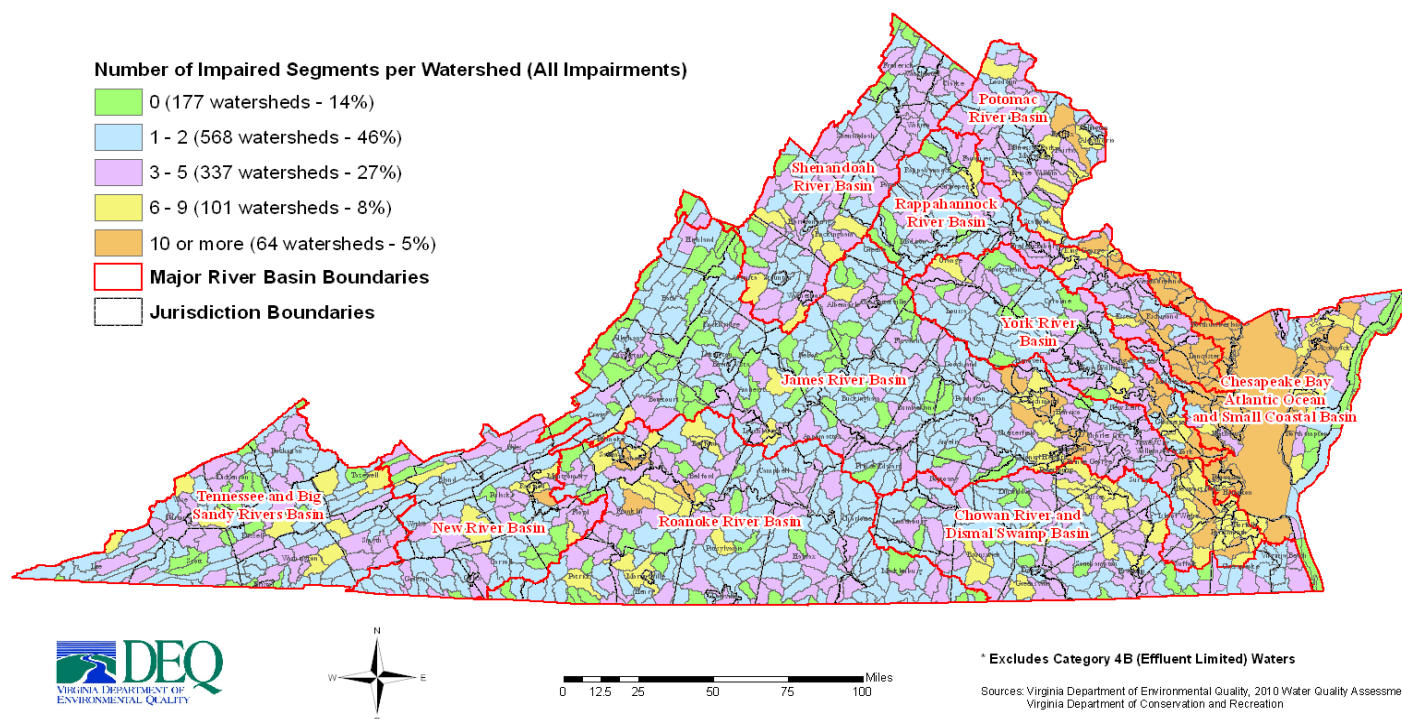
How does it happen and what are the consequences?

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PG 49

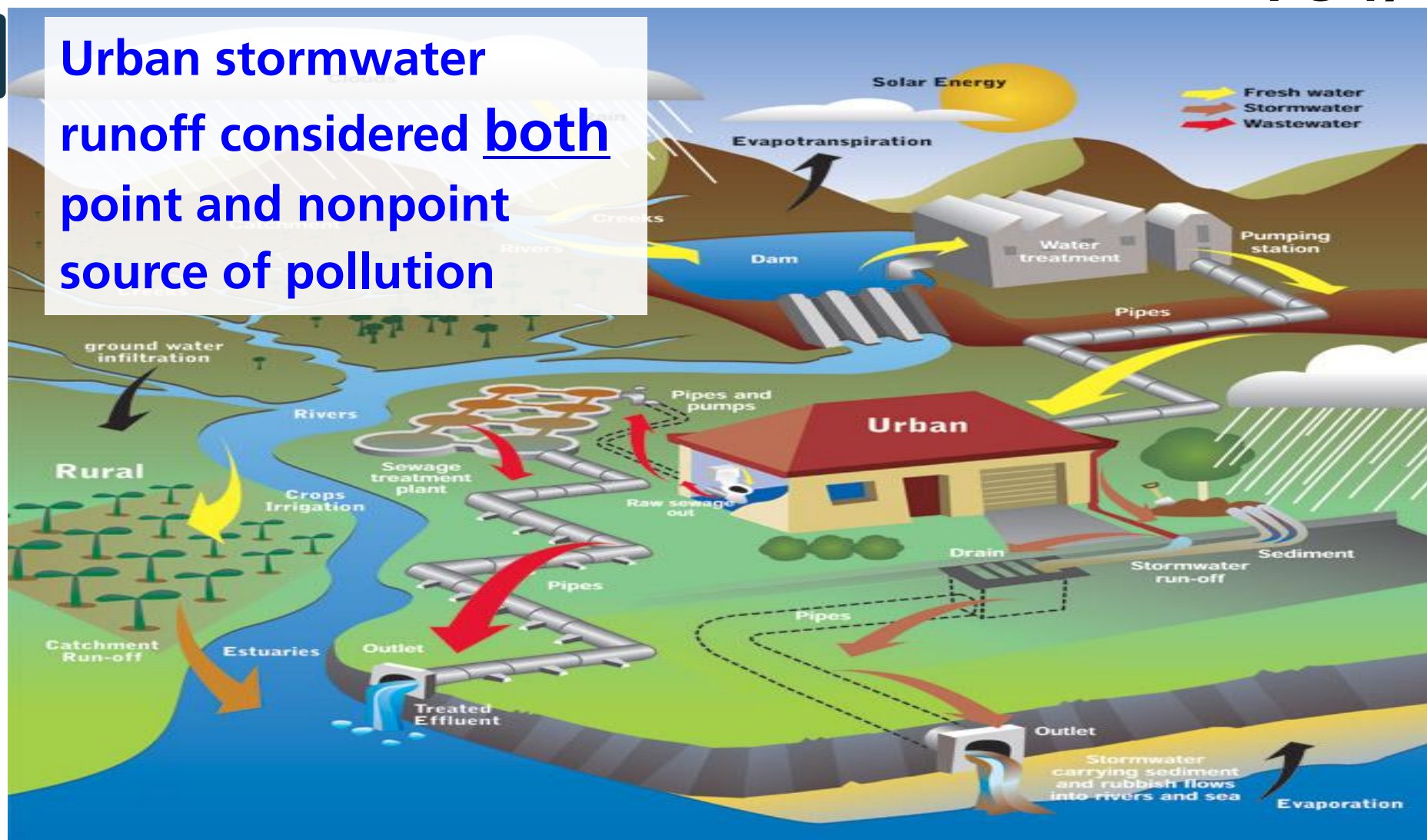
IV. Water quality impacts

Water quality impacts

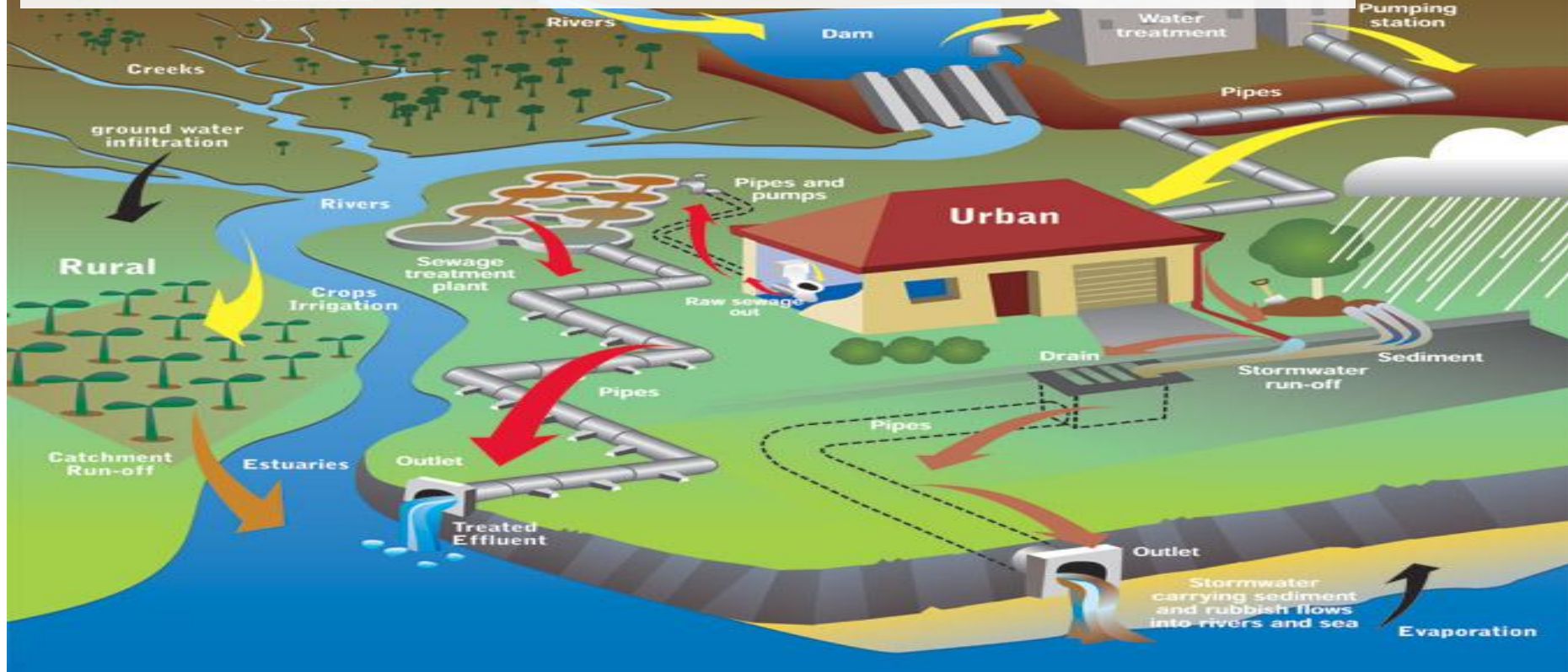
Distribution of Impaired* Waters in Virginia's Watersheds



Urban stormwater runoff considered both point and nonpoint source of pollution



Point sources describe discharges from conveyance systems (pipes, ditches, channels, other structure – discrete location or point on map)



Nonpoint sources describe diffuse scattered pollution sources picked up by runoff that flows across land surface



Development concentrates and increases nonpoint source pollutants and can also increase point source pollutants (eg. combined sewer overflows)



Water quality impacts



➤ Both point and nonpoint sources of urban stormwater runoff are:

➤ significant causes of water quality impairments to rivers and streams

Water quality impacts



➤ Contribute excess nutrient enrichment to lakes and ponds throughout state (continued threat to estuarine waters and the Chesapeake Bay)



Water quality impacts

According to USEPA,

The two primary sources of Water Quality Impairments to nation's estuaries are:

- 1. Agriculture**
- 2. Stormwater runoff**

Pollutant Sources


Module 2
PG 51-52



Stormwater collection and conveyance systems provide efficient concentrating transport to downstream receiving waters

➤ loss of natural processes which reduce quantity of runoff and remove pollutants: infiltration, interception, depression storage, evaporation, filtration by vegetation and ground

How does development contribute to pollutant loads?



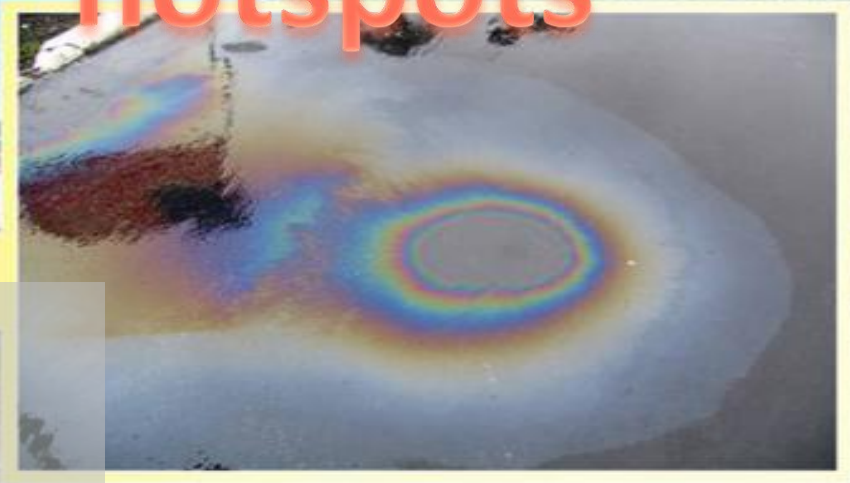
post-development areas like lawns, landscaped areas, on compacted soils are nearly impervious and contribute increased runoff and pollutants (leached nutrients, pesticides)

How does development contribute to pollutant loads?

Module 2
PG 53-54

stormwater “hotspots”

Certain land use activities are known to produce higher pollutant loads (trace metals, petroleum hydrocarbons, toxic chemicals)



How does development contribute to pollutant loads?


Module 2
PG 54



Rainfall volumes
of 1-inch or more
must be treated
to capture
majority of
pollutant load

**First Flush can be
as little as
20% annual runoff
pollutant load**

Pollutants

- 
- Solids, suspended solids, particulates
 - Excess Nutrients
 - Pathogens
 - Trace Metals



Other Pollutants

- Pesticides/Synthetic Organic Chemicals
- Chlorides/Deicing Constituents
- Trash and Debris
- Thermal Impacts
- Freshwater Impacts into brackish/tidal areas

Pollutants



Annual biomass generated by lawn clippings is equivalent to 272 million bushels of corn

(over 6.8 million tons - fill over 17,400 standard corn silos).



Pollutants



An estimated \$600 million annually is spent on lawn fertilizer and pesticides across the Bay watershed



Pollutants



Nitrogen fertilizer applied to lawns in the Bay watershed estimated to be nearly 215 million pounds/yr (enough to grow almost 2 million acres of corn)

Pollutants



~19 million lbs of pesticide active ingredients used each year (weed killers)

USGS – pesticides detected in 99% of urban streams (1 of 5 samples exceeded WQS)

Stormwater Pollutant	Potential Sources	Receiving Water Impacts	Removal Promoted by
Excess Nutrients Nitrate, Nitrite, Ammonia, Organic Nitrogen, Phosphate, Total Phosphorus	Animal waste, fertilizers, failing septic systems, landfills, atmospheric deposition, erosion and sedimentation, illicit sanitary connections	Algal growth, nuisance plants, ammonia and nitrate toxicity, reduced clarity, oxygen deficit (hypoxia), pollutant recycling from sediments, decrease in submerged aquatic vegetation (SAV), eutrophication, loss of recreation and aesthetic value	Phosphorus: Filtering/settling sediment, high soil exchangeable aluminum and/or iron content, vegetation and aquatic plants, alum in pond Nitrogen: Aeration, alternating aerobic and anaerobic conditions, maintaining near neutral pH (7)



How does it happen and what are the consequences?

V. Impacts on other receiving environments

Wetlands Ponds Estuaries

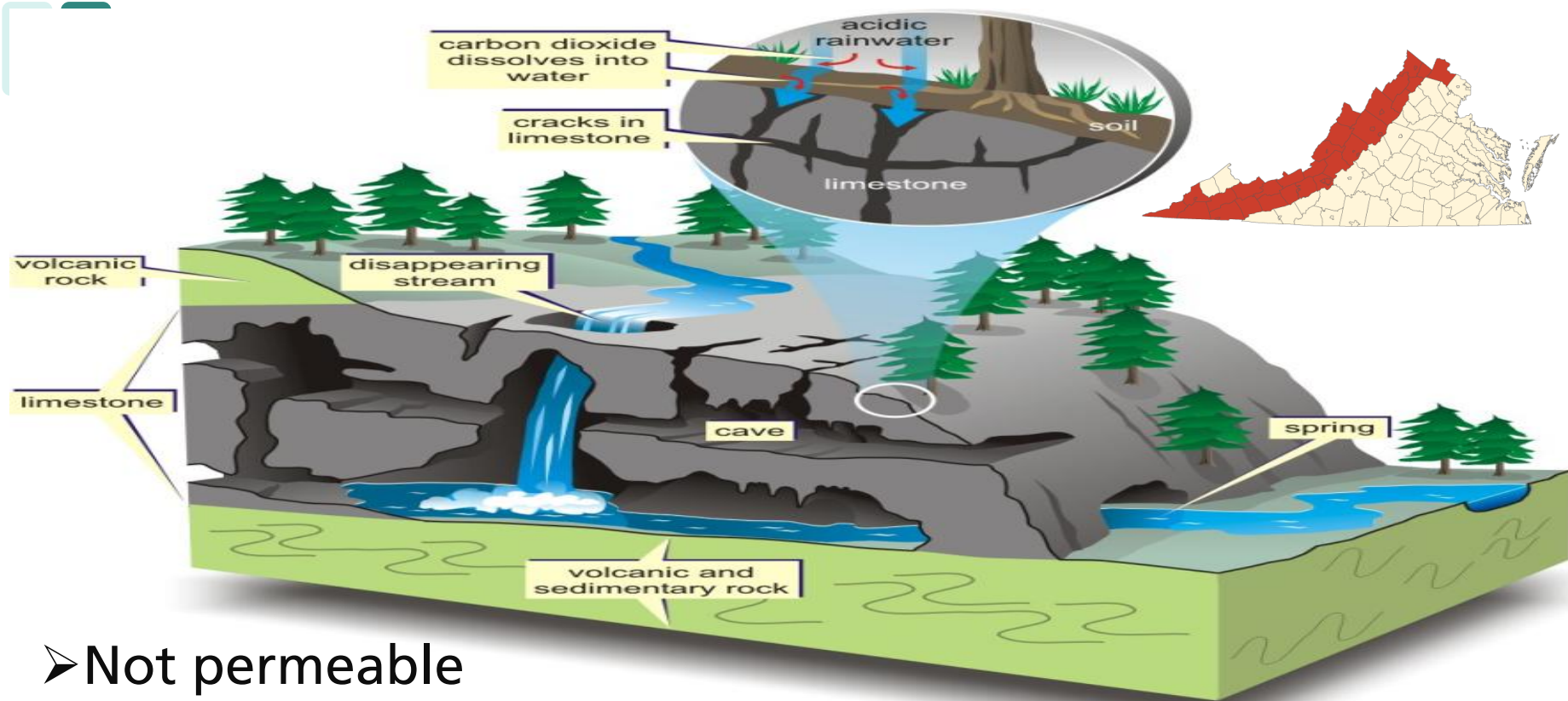


- Pollutant sink (nutrients, metals, sediments are not quickly flushed out)
- Accelerated eutrophication
- Sediment deposition and turbidity impact biota
- Loss of habitat and particular biota

Karst Systems



Karst Terrain



- Not permeable
- Diversion of rainwater
- No natural ground filtration

Karst Systems



- Erosion and underground sediment deposition
- Decreased recharge of aquifers
- Transport of pollutants directly to groundwater
- More sinkholes



Social and Economic Costs

- Floodwaters that lead to property and structural damages, road hazards
- Impairment/Impacts to drinking water supplies (reduced reservoir capacity due to sediment deposition, diminished groundwater supplies, contamination)
- increased cost for pollution remediation or water treatment
- Loss of beneficial uses (recreational, fisheries, shellfish harvesting)

Why Stormwater Management Matters - Summary



High Stormwater Volume and Velocity

- more impervious surfaces lead to less ground infiltration, more higher energy runoff
- increased stream volumes and flow rates, flooding, more erosion

Why Stormwater Management Matters



Pollutants in Stormwater Runoff

- Pollutants transported untreated to our waterways

(nutrients, sediments, toxics, litter, debris, bacteria and pathogens, higher water temps)

Why Stormwater Management Matters



Ecological Impacts

- Altered or lost habitats (aquatic, riparian)
- Reduced species richness and diversity
- Shift in ecological balance (aquatic food sources, opportunistic species)

Why Stormwater Management Matters




Loss of Beneficial Uses

- Reduction in desirable fish species
- Shellfish contamination
- Contamination of drinking water
- Contamination of beaches
- Loss of recreation and aesthetic value



What do we do?



**Manage
Stormwater
Quantity and Quality**



Stormwater:

Then

Nuisance

= Dispose quickly



Stormwater:



Now

**Valuable Resource
(if managed wisely)**

= supply underground aquifers
(drinking water)

= provide additional source of
non-potable water

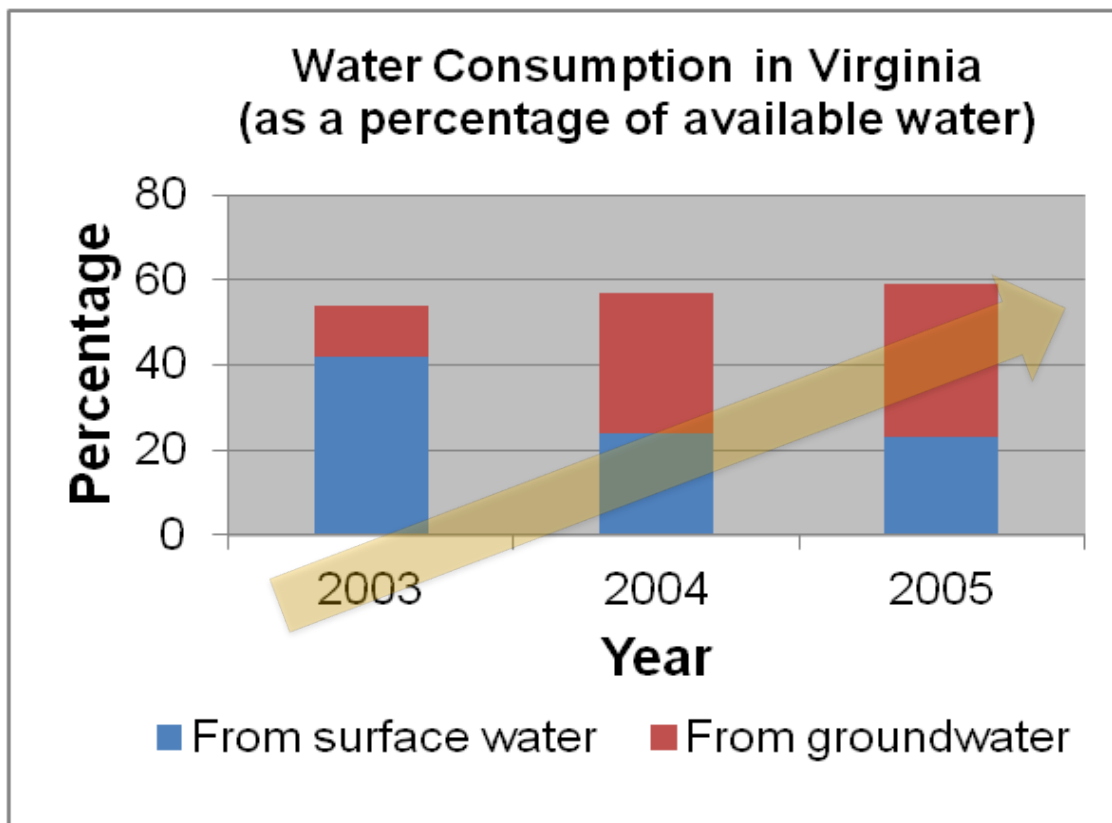
= can prevent/minimize damage
to public and private resources

Stormwater as a Valuable Resource



Stormwater as a Valuable Resource

Water
Demand



Stormwater as a Valuable Resource



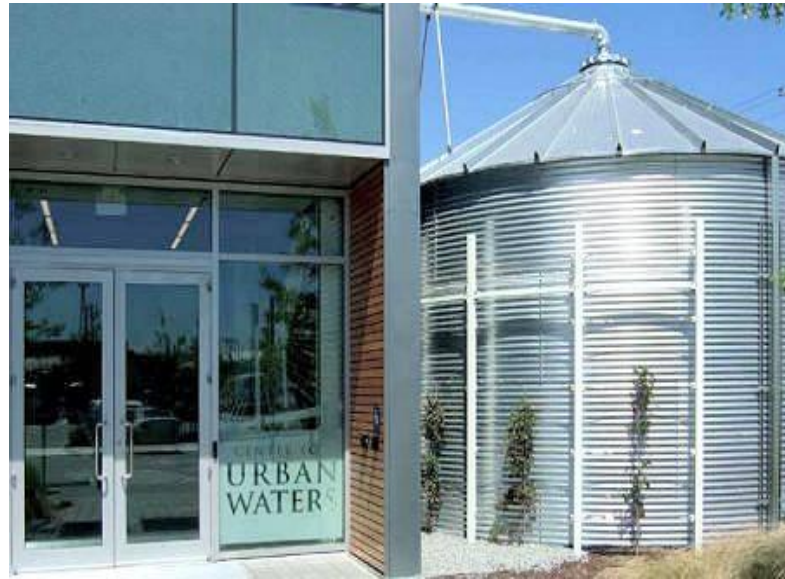
Water Supply

- water treatment plants struggling to keep up with current demands
- more runoff = less groundwater
- decreased stream base flow (and clean water supply)

Stormwater as a Valuable Resource

Rainwater Harvesting

- *Can be harvested from rooftops
- *Affordable, simple, sustainable way to provide alternative water source for non-potable uses



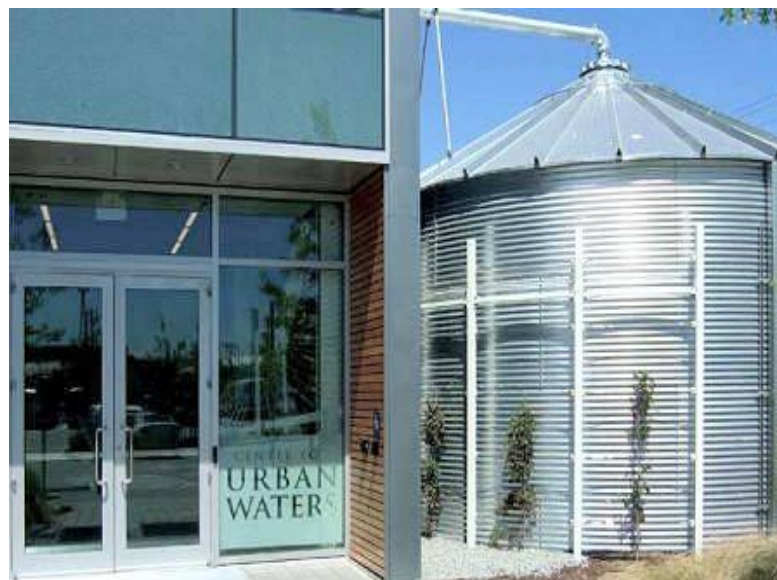
Stormwater as a Valuable Resource

**Creative
solution!**

Rainwater Harvesting

*encouraged in VA
SWMP regulations
(9VAC25-870-74)

*included as a VA non-
proprietary BMP






What next?

- **Stormwater runoff reduction via Low Impact Development (LID) practices** are being required for new developments in Virginia and other states (state and local authorities)
- Virginia building codes and health regulations are currently being reviewed to enable more extensive use of **rainwater harvesting** options



What do we do?

****take proactive approaches** 
(before, during, and after land development

****move beyond less effective traditional stormwater
management approaches** 

****control flooding and erosion** 

****prevent hazardous materials from polluting environment** 



What do we do?

****construct stormwater systems/utilize effective BMPs to remove contaminants and detain/slow down stormwater runoff**



****protect natural waterways**



****focus on maintaining natural land conditions**



****educate communities about how they can improve water quality and what the benefits are of doing so**





Economic Benefits



➤ Economic value of Chesapeake Bay to economies of Virginia and Maryland through commercial fishing, marine trade, water recreation and tourism, port activities, and land values is estimated at:

\$1 trillion



Economic Benefits



Implementing sound stormwater management regulations and programs can be economically beneficial:

1. Income generated by economic activities that rely on water and related natural resources; and
2. A reduction in or avoidance of costs which may result from environmental degradation and consumption of natural resources

Knowledge Check



Rainwater harvesting presents an option that could alleviate pressures on water supplies in Virginia. What are some of these pressures?

Answer: Water treatment plant capacity (struggle to keep up with demands); groundwater sources becoming increasingly depleted (more runoff); decreased stream base flow (clean water supply)



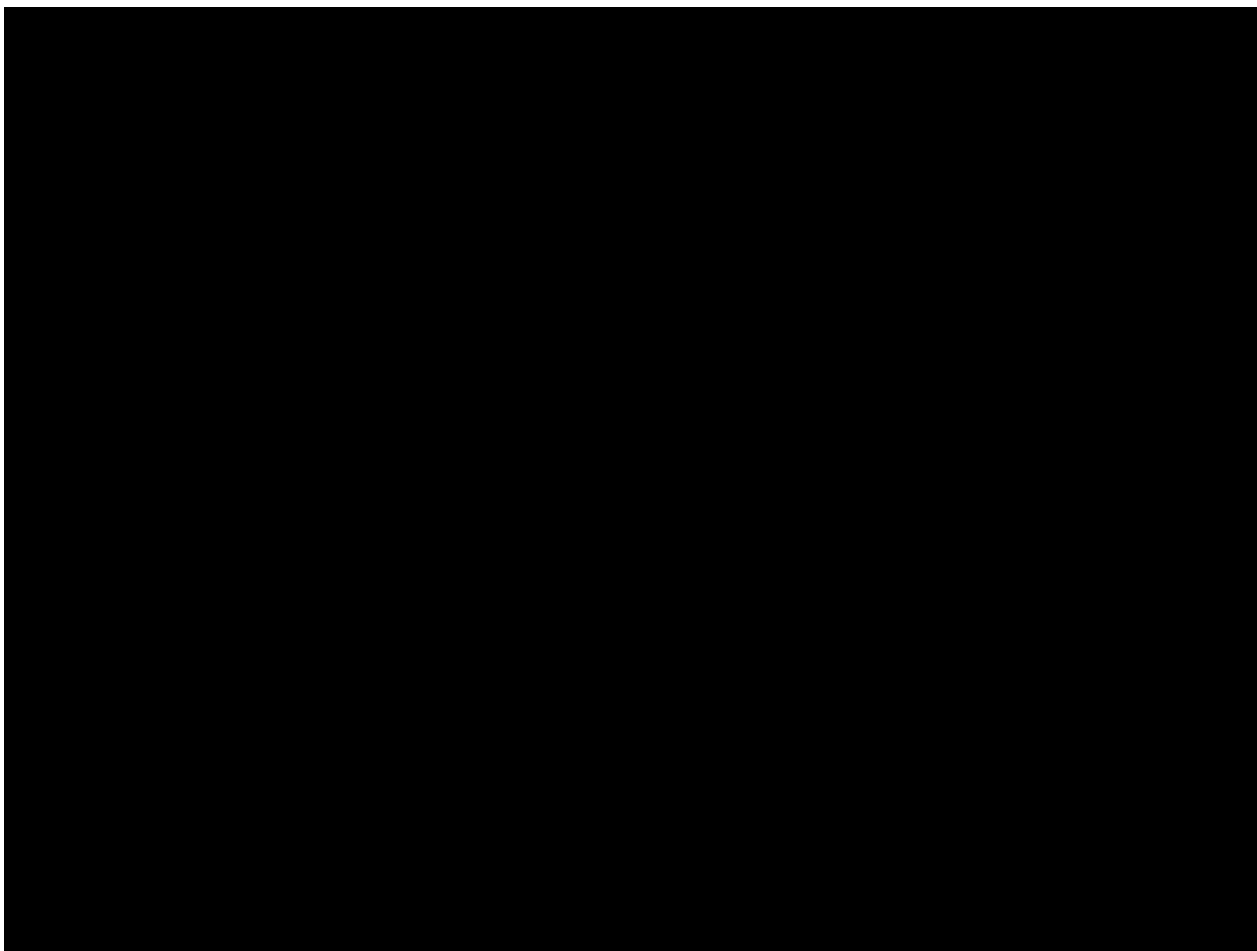
Knowledge Check



- How does increasing surface runoff change groundwater recharge rates?

DECREASE

Review treat:



End of Module 2